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Recommended Practice for Measurement of Exhaust Sulfate Emission from Light-Duty Vehicles and Trucks

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Recommended Practice

for

Measurement of Exhaust Sulfate Emission

from

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September, 1977

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16. Abstracts: Various test procedures for the measurement of exhaust sulfate (measured as sulfuric acid) emission from light-duty vehicles and trucks are described. Several test sequences were examined and the conclusion was reached that the sulfuric acid test should follow the exhaust emission measurements in the test sequence. This paper is structured in Federal Register format. This format incorporates sulfuric acid testing for the 1979 and later model years, although this is not to be taken as an indication that a sulfuric acid emission standard will be promulgated for the 1979 model year. Any sections in the current Federal Emission Test Procedure (Subpart B) which are affected by the incorporation of sulfuric acid testing are included in this recommended practice.

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General Introduction

This document describes recommended test procedures for the measurement of exhaust sulfate (measured as sulfuric acid) emission from light-duty vehicles and trucks. Because of possible relationships between gaseous and sulfuric acid exhaust emissions and possible effects of vehicle preconditioning on sulfuric acid emission levels,[1] it is desireable to measure both gaseous and sulfuric acid emission in a well defined sequence. Various different sequences were considered and evaluated in reference (1) and one of these was recommended as being the most appropriate. This recommended practice is consistent with the sequence recommended in the cited reference, ie., the sulfuric acid test is conducted after completion of the exhaust (and evaporative) emission testing.

Because of overlapping areas in the gaseous and sulfate test procedures, this document is structured in Federal Register format (as published on August 23, 1976, pgs. 35632-35651) in order to be as clear and unambiguous as possible. This format incorporates sulfuric acid testing for the 1979 and later model years, although this is <u>not</u> to be taken as an indication that a sulfuric acid emission standard will be promulgated for the 1979 model year. Any sections in the current Federal Emission Test Procedure (Subpart B) which are affected by the incorporation of sulfuric acid testing are included in this recommended practice. All changes to the current procedure are enclosed in brackets, [ ], as an aid to the reader. Sections which pertain entirely to sulfuric acid measurement are identified in the Table of Contents by braces, {}..

This document contains minor changes to the "Recommended Practice for Measurement of Exhaust Sulfuric Acid Emission from Light-Duty Vehicles and Trucks", dated November 1976, which is now superseded.

1 "Incorporation of a Test for Exhaust Sulfate Emissions into the Federal Emission Testing Procedure", Michael W. Leiferman, U.S. EPA, Ann Arbor, Michigan, December, 1975.

Table of Contents

	Section	
	86.101-78	Applicability.
✓	86.101-79	Applicability.
	86.102-78	Definitions.
✓	86.102-79	Definitions.
	86.103-78	Abbreviations.
✓	86.103-79	Abbreviations.
	86.104-78	Section numbering, construction.
	86.105-78	Introduction; structure of subpart.
✓	86.105-79	Introduction; structure of subpart.
	86.106-78	Equipment required, overview.
✓	86.106-79	Equipment required, overview.
	86.107-78	Sampling and analytical system, evaporative emissions.
	86.108-78	Dynamometer.
	86.109-78	Exhaust gas sampling system.
	86.110-78	Reserved.
✓	{86.110-79}	Sulfate sampling system.
	86.111-78	Exhaust gas analytical system.
	86.112-78	Reserved.
✓	{86.112-79}	Sulfate analytical system.
	86.113-78	Fuel specifications.
✓	86.113-79	Fuel specifications.
	86.114-78	Analytical gases.

86.115-78	EPA dynamometer driving schedules.
✓ 86.115-79	EPA dynamometer driving schedules.
86.116-78	Calibrations, frequency and overview.
✓ 86.116-79	Calibrations, frequency and overview.
86.117-78	Evaporative emission enclosure calibrations.
86.118-78	Dynamometer calibration.
86.119-78	Constant volume sampler calibration.
86.120-78	Reserved.
✓ {86.120-79}	Gas meter calibration, sulfate measurement.
86.121-78	Hydrocabon analyzer calibration.
86.122-78	Carbon monoxide analyzer calibration.
86.123-78	Oxides of nitrogen analyzer calibration.
86.124-78	Carbon dioxide analyzer calibration.
86.125-78	Reserved.
✓ {86.125-79}	Sulfate analysis system calibration.
86.126-78	Calibration of other equipment.
86.127-78	Test procedures, overview.
✓ 86.127-79	Test procedures, overview.
86.128-78	Transmissions.
✓ 86.128-79	Transmissions.
86.129-78	Road load power and inertia weight determination.
86.130-78	Test sequence, general requirements.
✓ 86.130-79	Test sequence, general requirements.
86.131-78	Vehicle preparation.
86.132-78	Vehicle preconditioning.
✓ 86.132-79	Vehicle preconditioning.
86.133-78	Diurnal breathing loss test.

	86.134-78	Running loss test.
	86.135-78	Dynamometer procedure.
✓	86.135-79	Dynamometer procedure.
	86.136-78	Engine starting and restarting.
	86.137-78	Dynamometer test run, gaseous emissions.
✓	86.137-79	Dynamometer test run, gaseous emissions.
	86.138-78	Hot soak test.
✓	86.138-79	Hot soak test.
	86.139-78	Reserved.
✓	{86.139-79}	Dynamometer test run, sulfate test.
	86.140-78	Exhaust sample analysis, gaseous emissions.
	86.141-78	Reserved.
✓	{86.141-79}	Exhaust sample analysis, sulfate emission.
	86.142-78	Records required.
✓	86.142-79	Records required.
	86.143-78	Calculations, evaporative emissions.
	86.144-78	Calculations, gaseous exhaust emissions.
	86.145-78	Reserved.
✓	{86.145-79}	Calculations, sulfate emission.

✓ = sections contained in this document. For other sections, see 42 FR 32906 (June 18, 1977).

§86.101-79 General applicability.

(a) The provisions of this subpart are applicable to 1977 and later model year new light duty vehicles and light duty trucks.

[(1) Sections ending in "-79" apply for 1979 and later model years.]

(2) Sections §86.101-78 through §86.145-78 apply for 1978 and later model years.

(3) Sections §86.177-5 through §86.177-23 apply for the 1977 model year.

(b) Provisions of this subpart apply to tests performed by both the Administrator and motor vehicle manufacturers.

§86.102-79 Definitions.

The definitions in §§86.077-2, 86.078-2 [and 86.079-2] apply to this subpart.

§86.103-79 Abbreviations.

The abbreviations in §§86.078-3 [and 86.079-31] apply to this subpart.

§86.105-79 Introduction, structure of subpart.

(a) This subpart describes the equipment required and the procedures to follow in order to perform [gaseous] exhaust, [exhaust sulfuric acid] and evaporative emission tests on light duty vehicles and light duty trucks. Subpart A sets forth the testing requirements and test intervals necessary to comply with EPA certification procedures.

(b) Three topics are addressed in this subpart. Sections 86.106 through 86.115 set forth specifications and equipment requirements; §§86.116 through 86.126 discuss calibration methods and frequency; test procedures and data requirements are listed (in approximately [chronological order]) in §§86.127 through 86.145.

§86.106-79 Equipment required; overview.

(a) This subpart contains procedures for both exhaust and evaporative emissions tests on gasoline or diesel fueled light duty vehicles and light duty trucks. Certain items of equipment are not necessary for a particular test, e.g., evaporative enclosure when testing diesel vehicles. Equipment required and specifications are as follows:

(1) Evaporative emission tests, gasoline fueled vehicles. The evaporative emission test is closely related to and connected with the exhaust emission test. All vehicles tested for evaporative emissions must be tested for exhaust emissions. Further, unless the evaporative emission test is waived by the Administrator under §86.077-26, all gasoline fueled vehicles must undergo both tests. (Diesel vehicles are excluded from the evaporative emission standard.) Section 86.107 specifies the necessary equipment.

(2) Exhaust emission tests. All vehicles subject to this subpart are tested for exhaust emissions. [Generally, diesel and gasoline fueled vehicles are tested identically. However, diesel vehicles require a heated hydrocarbon detector and do not undergo a diurnal heat build.] Equipment necessary and specifications appear in section 86.108 through 86.114.

(3) Fuel, analytical gas, and driving schedule specifications. Fuel specifications for exhaust and evaporative emissions testing

and for mileage accumulation are found in §86.113. Analytical gases are specified in §86.114. [Two driving schedules are used:

(i) The EPA Urban Dynamometer Driving Schedule (UDDS) for use in gaseous exhaust emission testing is specified in §86.115 and Appendix I.

(ii) The EPA Congested Freeway Dynamometer Driving Schedule (CFDDS) for use in sulfuric acid emission testing is specified in §86.115 and Appendix VIII.]

[§86.110-79 Sulfate sampling system.

(a)(1) Schematic drawings.

(i) Figure B79-1 is a schematic drawing of the PDP-CVS and Figure B79-2 is a schematic drawing of the CFV-CVS. These are two suggested sulfuric acid sampling systems.

(ii) Bag sampling capabilities as previously shown in Figures B78-1 and B78-2 can be added to the systems shown in Figures B79-1 and B79-2, respectively, to provide both gaseous and sulfuric acid emissions sampling capabilities from a single system.

(iii) If the background sulfuric acid level is to be measured, a bag sample of dilute exhaust gas is necessary for determination of the CO_2 level. The measurement of sulfuric acid background is optional as explained in §86.145.

(2) Since various configurations can produce equivalent results, exact conformance with these drawings is not required. Additional components such as instrument, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the component systems.

(3) Other Systems. Other sampling systems may be used if shown to yield equivalent results and if approved in advance by the Administrator.

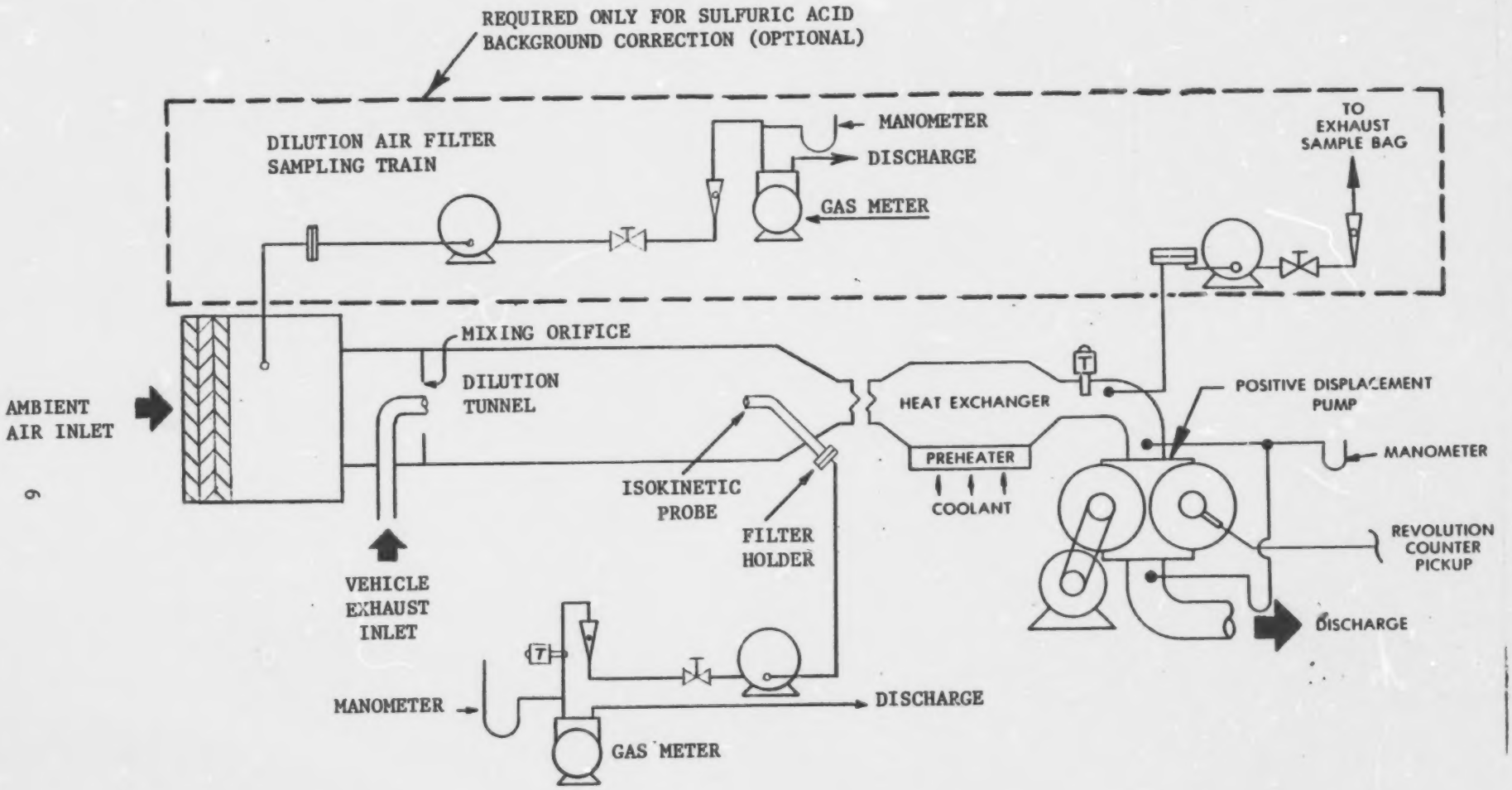

FIGURE B79-1 SULFURIC ACID SAMPLING SYSTEM (PDP-CVS)

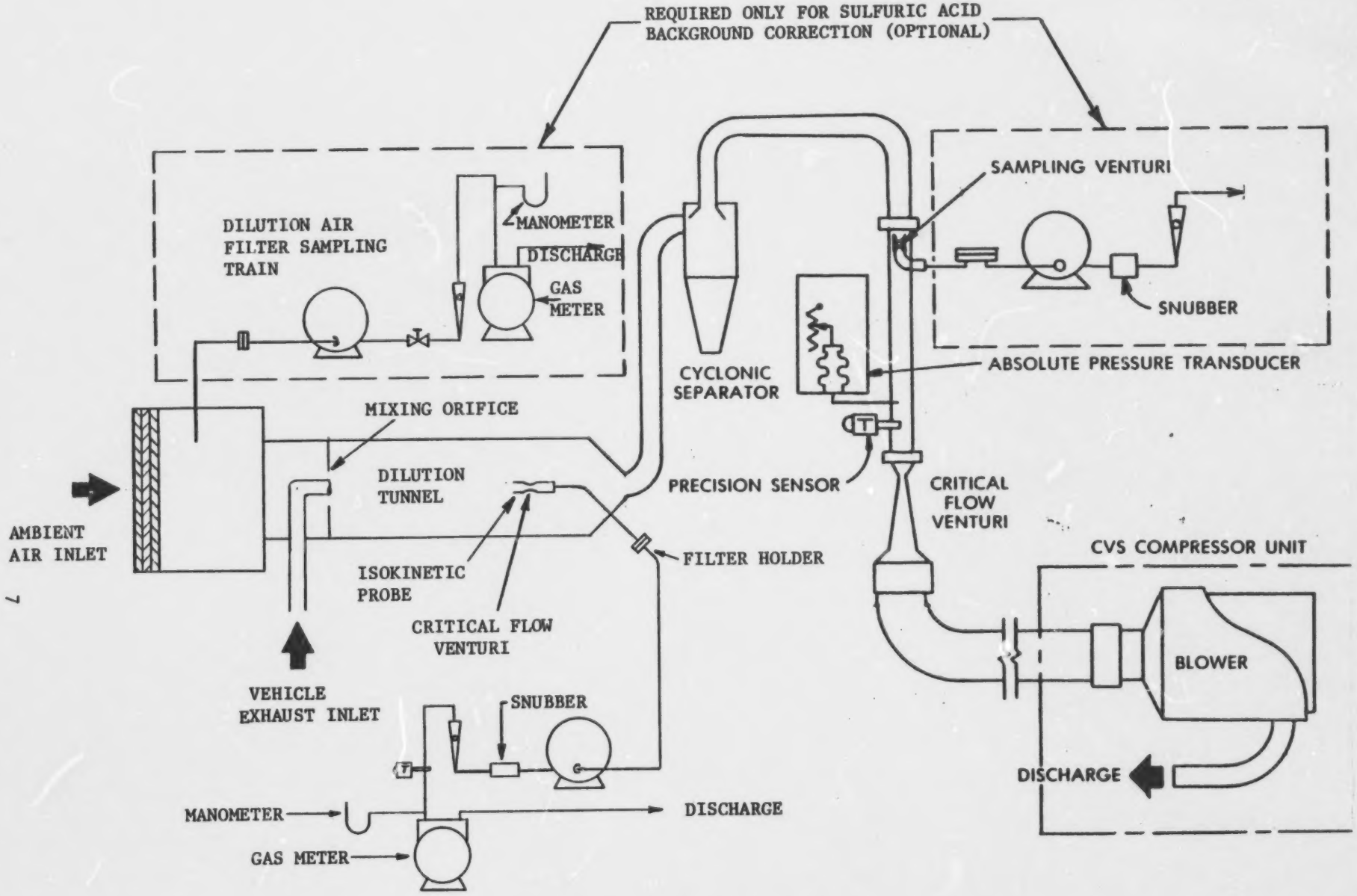

FIGURE B79-2 SULFURIC ACID SAMPLING SYSTEM (CFV-CVS)

(b) Component description, PDP-CVS. The PDP-CVS, Figure B79-1, shall conform to all of the requirements listed for the exhaust gas PDP-CVS (§86.109(b)), except gaseous sampling equipment is optional as explained in §86.145. It is also possible that a flow rate of greater than 350 CFM may be necessary. In addition, there are several components necessary for sulfuric acid sampling. These components shall meet the following requirements:

(1) The dilution tunnel shall be:

(i) sized to permit development of turbulent flow (Reynold's No. > 4000) and complete mixing of the exhaust and dilution air between the mixing orifice and the isokinetic sample probe.

(ii) large enough in diameter to permit isokinetic sampling through the probe as required in paragraph (c)(2) of this section.

(iii) constructed of a material which does not react with the exhaust components.

(2) The probe shall be:

(i) located on approximately the tunnel centerline and facing upstream.

(ii) sized to permit isokinetic sampling.

(iii) 0.95 cm (0.375 in) minimum inside diameter.

(iv) as short as practical from sampling tip to the filter holder which shall be located outside of, but close to, the tunnel.

(v) free from sharp bends.

(3) The sample pump shall be:

(i) located sufficiently far from the tunnel so that the inlet gas temperature is maintained at a constant temperature (± 3°C) which is approximately room temperature.

(ii) of sufficient capacity to maintain isokinetic flow into the probe throughout the test.

(4) The flow rate through the probe shall be:

(i) within 10% of isokinetic at all times throughout the test as determined by assuming uniform flow radially across the dilution tunnel; and

(ii) at least .24 l/sec (0.50 CFM)

(5) The temperature of the vehicle exhaust gas from the point where it leaves the vehicle tailpipe(s) to the point where it enters the dilution tunnel airstream, shall be high enough to prevent water and sulfuric acid condensation. To accomplish this, a short length (e.g., not more than 2.5 meters) of 6.4 cm (2.5 in) I.D. insulated flexible stainless steel tubing from the tailpipe to the tunnel has been found to work satisfactorily. With adequate insulation, longer lengths may also be satisfactory. The section of ducting which carries the exhaust gas through the wall of the tunnel may also require insulation.

(6) The temperature inside the dilution tunnel shall be sufficient to prevent water condensation and prevent more than 3% sulfuric acid loss in each the dilution tunnel and the sample probe. This is determined by thoroughly rinsing the inside of the dilution tunnel and the sample probe with distilled water or IPA solution (which is defined in §86.110A) prior to a sulfuric acid test. After the test this equipment is again rinsed with the IPA solution and this rinse solution then analyzed for sulfuric acid content. A sampling zone dilute exhaust temperature range of between 40°C and 80°C has been found to work satisfactorily. At temperatures outside this range, excessive loss of sulfuric acid has been encountered.

(c) Component description, CFV-CVS. The CFV-CVS, Figure B79-2, shall conform to all of the requirements listed for the

exhaust gas CFV-CVS (§86.109(c)) and requirements in (b)(1) through (6) of this section, except gaseous sampling equipment is optional as explained in §86.145.

In general, the following requirements in addition to those for a PDP-CVS shall be met:

(1) The probe shall incorporate a critical flow venturi to ensure a sampling rate propotional to the main CFV flow rate.

(2) The flow capacity of the sample pump shall be sufficient to maintain critical flow through the sampling venturi throughout the test.

NOTE: Loss of sulfuric acid on the probe may show different characteristics when the probe is preceeded by a critical flow section than when the flow is unrestricted. Data from probe loss experiments using an unrestricted probe may not be applicable to CFV probes.

(d) Filters, sulfuric acid sampling.

(1) 1.0 micron nominal pore size filter shall be used.

(2) 47 mm nominal diameter is sufficiently large for most gasoline powered vehicles. Larger diameter filters are also

acceptable; and for vehicles with large amounts of exhaust particulates (e.g., diesels), larger diameter filters may be desirable in order to reduce the pressure drop across the filter.

(3) Fluorocarbon filter material or other materials which are sulfate free and do not react to cause spurious sulfate values shall be used with the analytical procedure specified in this part.]

[§86.112-79 Sulfate analytical system.

The function of this system is to determine the mass of sulfate ($SO_4^=$) on the filter.

(a) Schematic Drawings. Figures B79-3 and B79-4 are schematic drawings of an automated barium chloranilate filter analytical system. Figure B79-3 shows the system in the sample loading position and B79-4 shows the system in the sample injection position. The analytical system should require a minimum amount of sample for purging and loading the loop; preferably 5 ml or less. Since various configurations, including manually loaded and operated systems, can produce accurate results, exact conformance with these drawings is not required.

(b) Major component description. The analytical system, Figures B79-3 and B79-4, consists of a reservoir containing a solution of 60% isopropyl alcohol and 40% de-ionized distilled water (IPA solution), high pressure (HP) pump, 6 port-2 way valve, automatic sampler, peristaltic pump, cation exchange column containing a silver form cation exchange resin, cation exchange column containing a hydrogen form cation exchange resin, barium chloranilate column, ultraviolet (UV) chloranilic acid detector, and an integrator.

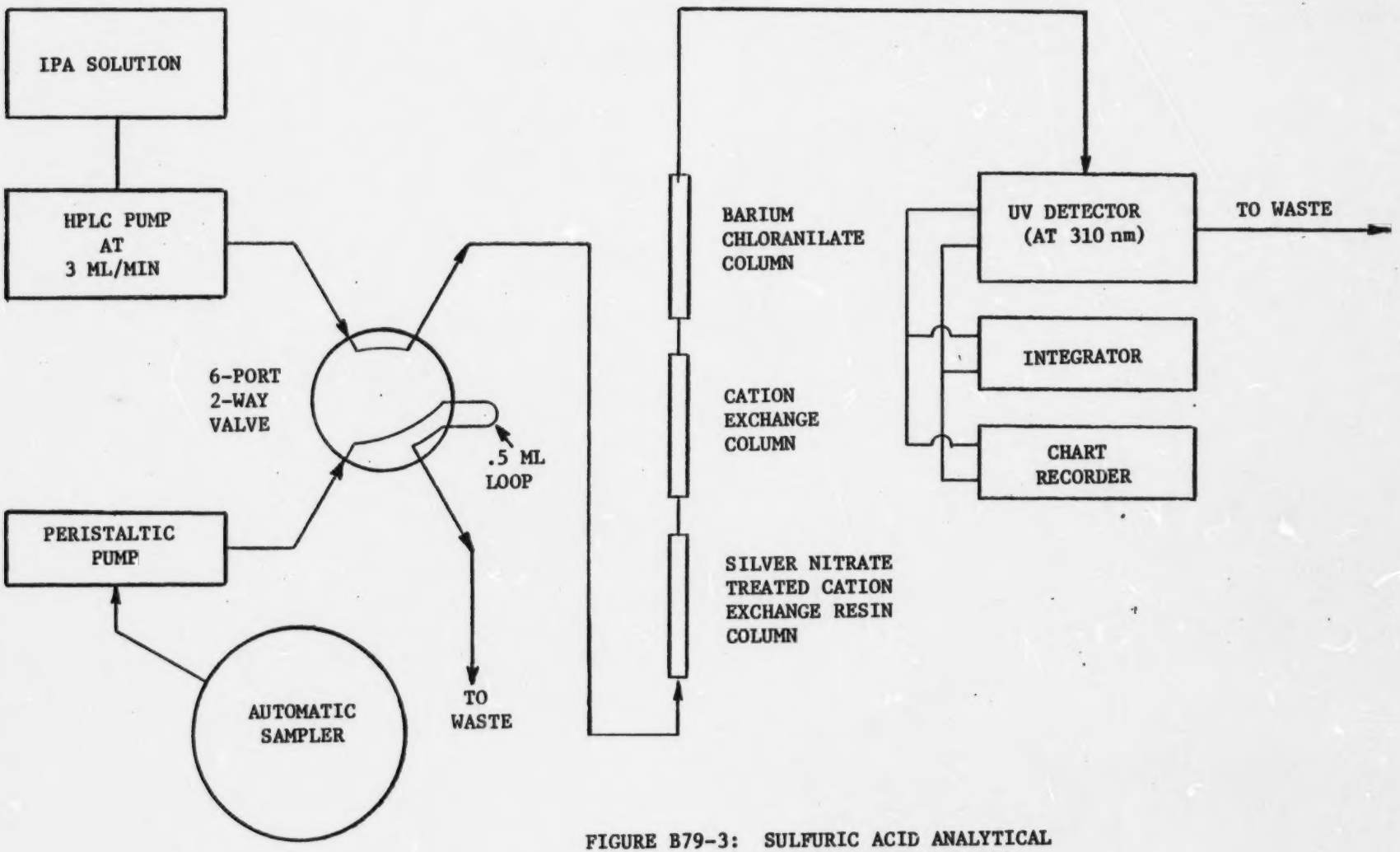

FIGURE B79-3: SULFURIC ACID ANALYTICAL SYSTEM (LOADING MODE)

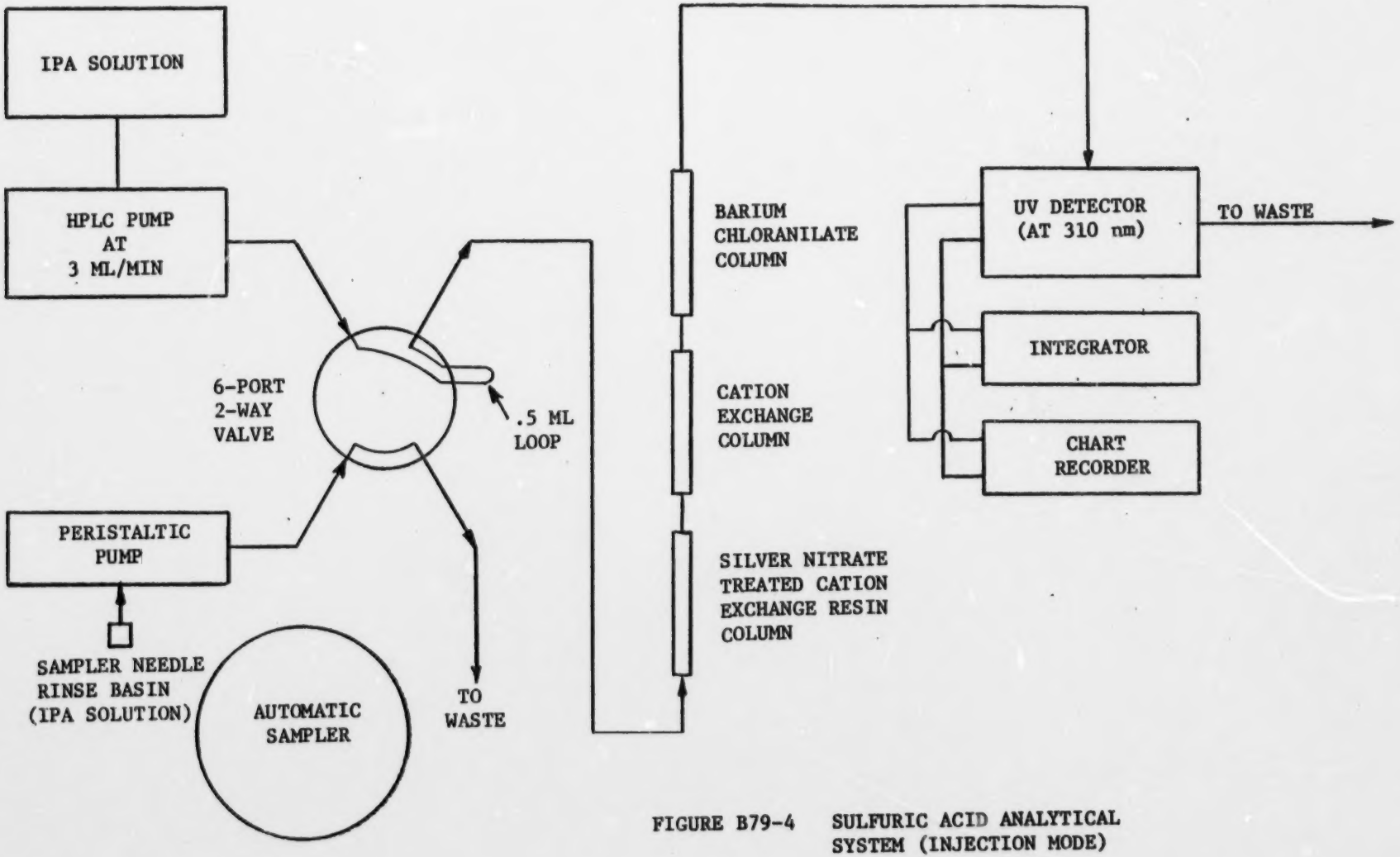

FIGURE B79-4 SULFURIC ACID ANALYTICAL SYSTEM (INJECTION MODE)

(c) Other analytical methods. A method utilizing titration with photometric end point determination has been shown to yield results which are equivalent to the barium chloranilate system. This method, as well as others, may be used if shown to yield equivalent results and if approved by the Administrator.]

§86.113-79 Fuel Specifications.

(a) Gasoline.

(1) Gasoline having the following specifications will be used by the Administrator in exhaust and evaporative emission testing. Gasoline having the following specifications or substantially equivalent specifications approved by the Administrator, shall be used by the manufacturer in exhaust and evaporative testing, except that the lead and octane specifications do not apply.

Item	ASTM	Leaded	Unleaded
Octane, research, minimum	D2699	98	93
Sensitivity, minimum		9.0	7.5
Pb. (organic), grams/U.S. gallon		1.4[1]	0.00-0.05
Distillation range:			
IBP[2], °F	D86	75-95	75-95
10 percent point, °F	D86	120-135	120-135
50 percent point, °F	D86	200-230	200-230
90 percent point, °F	D86	300-325	300-325
EP, °F (maximum)	D86	415	415
[Sulphur, wt. percent, maximum	D2622[3]	0.10[4]	0.10[4]]
Phosphorus, grams/U.S. gallon, maximum		.01	.005
RVP[5], pounds	D323	8.7-9.2	8.7-9.2
Hydrocarbon composition			
Olefins, percent, maximum	D1319	10	10
Aeromatics, percent, maximum	D1319	35	35
Saturates	D1319	Remainder	Remainder

1 Minimum

2 For testing at altitudes above 1,219 meters (4,000 feet) the specified range is 75-105.

3 Or other method of similar (or higher) sensitivity.

[4 For sulfuric acid testing, the specified range is 0.028-0.032.]

5 For testing at altitudes above 1,219 meters (4,000 feet) the specified range is 7.9-9.2.

(2) Gasoline representative of commercial gasoline which will be generally available through retail outlets shall be used in service accumulation [of non-catalyst vehicles.] For leaded gasoline the minimum lead content shall be 1.4 grams per U.S. gallon, except that where the Administrator determines that vehicles represented by a test vehicle will be operated using gasoline of different lead content than that prescribed in this paragraph, he may consent in writing to use of a gasoline with a different lead content. The octane rating of the gasoline used shall be no higher than 1.0 research octane numbers above the minimum recommended by the manufacturer. The Reid Vapor Pressure of the gasoline used shall be characteristic of the motor fuel used during the season in which the service accumulation takes place.

[(3) For service accumulation of catalyst equipped vehicles the specifications in paragraph (a)(2) of this section apply. In addition the sulfur content of the fuel used in vehicles to be tested for sulfuric acid emissions shall be 0.028 weight percent, minimum.

(4) The sulfur level of the gasoline shall be increased, when required to be consistent with (a)(1) or (3) of this section, by addition of an organic, sulfur containing compound such as thiophene (C_4H_4S).]

(5) The specification range of the gasoline to be used under paragraphs (a)(2) [and (3)] of this section shall be reported in accordance with 86.077-21(b)(3).

(6) The actual sulfur level of the gasoline used during testing shall be reported in accordance with the calculation procedure in §86.145.

(b) Diesel Fuel.

(1) The diesel fuels employed for testing shall be clean and bright, with pour and cloud points adequate for operability. The diesel fuel may contain nonmetallic additives as follows: Centane improver, metal deactivator, antioxidant, dehazer, antirust, pour depressant, dye and dispersant.

[(2) Diesel fuel meeting the following specifications, or substantially equivalent specifications approved by the Administrator, shall be used in exhaust emissions testing. "Type 2-D" grade diesel fuel shall be used.

Item	ASTM	Type 2-D
Cetane	D613	42-52
Distillation range	D 86	
IBP, °F		340-400
10 percent point, °F		400-460
50 percent point, °F		470-540
EP, °F		580-660
Gravity, °API	D287	33-37
Total Sulfur, wt percent	D2622[1]	0.2-0.5[2]
Hydrocarbon composition	D1319	
Aromatics, percent		27[3]
Paraffins, Naphtenes, Olefins		(4)
Flashpoint, °F (minimum)	D93	130
Viscosity, Centistokes	D445	2.0-3.2

[1] Or method of similar (or higher) sensitivity.

[2] For sulfate testing, the specified range is 0.200-0.250.

[3] Minimum.

[4] Remainder.]

[(3) Diesel fuel meeting the following specifications, or substantially equivalent specifications approved by the Administrator, shall be used in service accumulation. "Type 2-D" grade diesel fuel shall be used.

ITEM	ASTM test method No.	Type 2-D
Cetane	D613	38-58
Distillation range	D86	
90 percent point, °F		430-630
Gravity, °API	D287	30-42
Total Sulfur, wt. percent (minimum)	D2622[1]	0.20
Flashpoint, °F (minimum)	D93	130
Viscosity, Centistokes	D445	1.5-4.5

]

[1] Or method of similar (or higher) sensitivity

(4) Other petroleum distillation fuel specifications:

(i) Other petroleum distillate fuels may be used for testing and service accumulation provided they are commercially available, and

(ii) Information, acceptable to the Administrator, is provided to show that only the designated fuel would be used in customer service, and

(iii) Use of a fuel listed under paragraphs (b)(2) and (b)(3) of this section would have a detrimental effect on emissions or durability and

(iv) Written approval from the Administrator of the fuel specifications was provided prior to the start of testing.

(5) The specification range of the fuels to be used under paragraphs (b)(2), (b)(3), and (b)(4) of this section shall be reported in accordance with §86.077-21(b)(3).

[(6) The actual sulfur level of the fuel used during testing shall be reported in accordance with the calculation procedure in §86.145.]

§86.115-79 EPA Dynamometer Driving Schedules:

[(a) The two EPA dynamometer driving schedules are:

NAME	DISTANCE		TIME	AVG SPEED	
	mi	(Km)	S	mph	(Kph)
Urban	7.5	(12.1)	1372	19.7	(31.7)
Congested Freeway	13.5	(21.7)	1398	34.8	(55.9)]

(b) The dynamometer driving schedules are listed in [Appendices I and VIII.] A driving schedule is defined by a smooth trace drawn through the specified speed vs. time relationships. It consists of a non-repetitive series of idle, acceleration, cruise, and deceleration modes of various time sequences and rates.

(c) The speed tolerance at any given time on a dynamometer driving schedule prescribed in [Appendices I and VIII] or as printed on a driver's aid chart approved by the Administrator, when conducted to meet the requirements of §86.133 is defined by upper and lower limits. The upper limit is 2 mph (3.2 kph) higher than the highest point on the trace within 1 second of the given time. The lower limit is 2 mph (3.2 kph) lower than the lowest point on the trace within 1 second of the given time. Speed variations greater than the tolerances (such as may occur during gear changes) are acceptable provided they occur for less than 2 seconds on any occasion. Speeds lower than those prescribed are acceptable provided the vehicle is operated at maximum available

power during such occurrences. When conducted to meet the requirements of 86.128 the speed tolerance shall be as specified above, except that the upper and lower limits shall be 4 mph (6.4 kph).

(d) Figure B78-4 shows the range of acceptable speed tolerances for typical points. Figure B78-4(a) is typical of portions of the speed curve which are increasing or decreasing throughout the two second time interval. Figure B78-4(b) is typical of portions of the speed curve which include a maximum or minimum value.

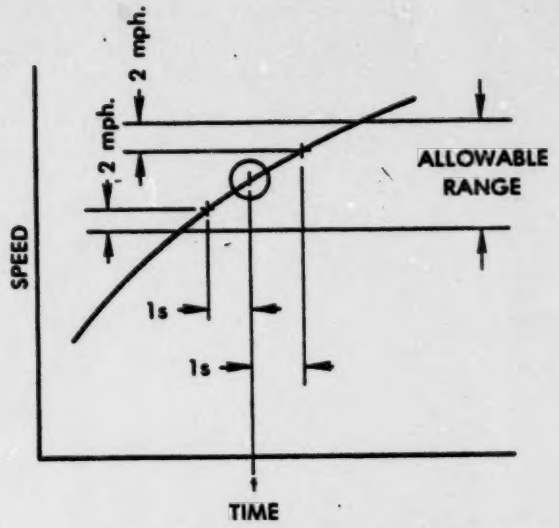

FIGURE B78-4a—DRIVERS TRACE, ALLOWABLE RANGE

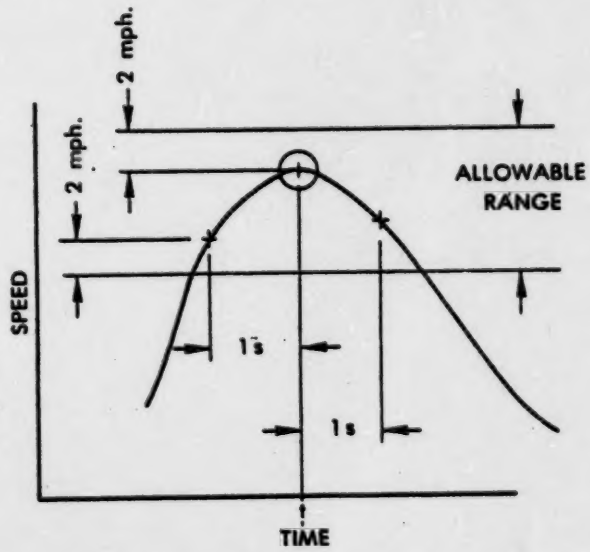

FIGURE B78-4b—DRIVERS TRACE, ALLOWABLE RANGE

§86.116-79 Calibrations, frequency and overview.

(a) Calibrations shall be performed as specified in §§86.117 through 86.126.

(b) At least yearly or after any maintenance, enclosure background emission measurements shall be performed.

(c) At least monthly or after any maintenance which could alter calibration, the following calibrations and checks shall be performed:

(1) Calibrate the hydrocarbon analyzers (both evaporative and exhaust instruments), carbon dioxide analyzer, carbon monoxide analyzer, oxides of nitrogen analyzer.

(2) Calibrate the dynamometer. If the dynamometer receives a weekly performance check (and remains within calibration) the monthly calibration need not be performed.

(3) Perform a hydrocarbon retention check and calibration on the evaporative emission enclosure.

[(4) Calibrate the gas meter(s) used for providing total flow measurement for sulfuric acid sampling.]

(d) At least within the preceding week of any testing, or after any maintenance which could alter calibration, the following calibrations and checks shall be performed:

(1) Check the oxides of nitrogen converter efficiency.

(2) Perform a CVS system verification.

(3) Run a performance check on the dynamometer. This check may be omitted if the dynamometer has been calibrated within the preceding month.

(e) The CVS positive displacement pump or Critical Flow Venturi shall be calibrated following initial installation, major maintenance or as necessary when indicated by the CVS system verification (described in §86.119).

(f) Sample conditioning columns, if used in the CO analyzer train, should be checked at a frequency consistent with observed column life or when the indicator of the column packing begins to show deterioration.

[§86.120-79 Gas meter calibration, sulfate measurement.

Sampling for sulfuric acid exhaust emissions requires the use of a gas meter in the dilute exhaust sample line. This meter shall receive initial and periodic calibration as follows:

(a) Install a standard air flow measurement instrument upsteam of the gas meter. This standard instrument shall measure SCFM air flow with an accuracy of ± 1%. Standard conditions are defined as 273°K (32°F) and 101.3KPa (29.92 in. Hg.). A critical flow orifice or a laminar flow element is recommended as the standard instrument.

(b) Flow air through the calibration system at the isokinetic sampling flowrate of the system and at the back pressure which occur during the sampling procedure.

(c) When the temperature and pressure in the system have stabilized, measure the gas meter indicated volume over a time period of at least 5 minutes and until a flow volume of at least ± 1% accuracy can be determined by the standard instrument. Record the stabilized air temperature and pressure upstream of the gas meter and as required for the standard instrument.

(d) Calculate SCFM as measured by both the standard instrument and the gas meter.

(e) Repeat the procedure of paragraph (b) through (d) above using flow rates which are 10% above the isokinetic flowrate and 10% below the isokinetic flowrate.

(f) If the SCFM measured by the gas meter differs by more than $\pm$ 1% from the standard measurement at any of the three measured flow rates, then a correction shall be made by either of the following two methods:

(1) Mechanically adjust the gas meter so that it agrees within 1% of the standard measurement, or

(2) Develop a calibration curve for the gas meter from the three calibration points. A correction factor for the gas meter, at any flow rate which differs by more than 1% from the standard instrument is defined as:

$$K_m = \frac{\text{SCFM as measured by standard instrument}}{\text{SCFM as measured by gas meter}} .]$$

[§86.125-79 Sulfate analysis system calibration.

Calibration of an automated barium chloranilate system is described below. Other methods of using the barium chloranilate system and other methods of analysis are acceptable provided they give equivalent results and are approved in advance by the Administrator.

(a) Composition of Solvent.

(1) The Solvent (60/40 IPA) used in the high pressure pump and for the standards and samples is 60% (by volume) spectral grade isopropyl alcohol and 40% de-ionized, distilled water. The water used should have a specific resistance of at least 0.5 megohmn, to prevent rapid depletion of the cation exchange column and possible inaccurate results.

(2) Batch to batch variations in the solvent composition can cause erroneous responses during analysis. Several gallons should be made at one time and stored in a closed polypropylene container. Polypropylene containers are recommended because some glass and polyethylene containers have been found to give erroneous results.

(3) In subsequent use, the solvent should be kept in an air-tight polypropylene container to prevent evaporation. Samples

and standards should be prepared from the same batch of solvent and must also be kept in air-tight polypropylene containers whenever possible. Evaporation of the solvent will cause a change in the 60/40 ratio which will result in an erroneous response.

(b) Determination of the linear range of the analyzing system.

NOTE: Volumetric flasks and pipettes used in the preparation of standards shall meet the NBS Class A accuracy specification.

(1) A gravimetric standard of approximately 50 micrograms sulfate ion ($SO_4^{=}$) per milliliter (ml) of solvent shall be prepared as follows:

(i) Heat ammonium sulfate crystals (reagent grade) to approximately 104°C (220°F) and allow to cool in a desiccator.

(ii) Weigh approximately 70 mg of the dry ammonium sulfate crystals from step (i) using a balance which has a precision of at least 0.01 mg, and record the weight.

(iii) Place the crystals into a clean one liter volumetric flask. Prior to use, this flask should be cleaned with nitric acid and copiously rinsed with distilled water and then rinsed

twice with 60/40 IPA solution. A portion of the final rinse IPA solution shall be analyzed for sulfuric acid by the analysis procedure of this section. If a response greater than a normal blank response is observed the cleaning procedure shall be repeated until no response is obtained.

(iv) Fill the flask to the "1 liter" mark with 60/40 IPA solvent.

(v) Mix the solvent until the crystals are dissolved.

(2) The concentration of the gravimetric standard in terms of sulfate ion ($SO_4^=$) concentration shall be calculated as follows:

$$SO_4^=(\mu g/ml) = \frac{\text{mass of } (NH_4)_2\ SO_4 (mg/1) \times 1000(\mu g/mg)}{1000\ ml/1} \times \frac{MW\ SO_4^=}{MW\ (NH_4)_2 SO_4}$$

Example: mass of $(NH_4)_2\ SO_4$ = 70.00 mg

MW $SO_4^=$ = 96.06

MW $(NH_4)_2\ SO_4$ = 132.14

$$\frac{70.00 \times 1000}{1000} \times \frac{96.06}{132.14} = 50.89\ \mu g\ SO_4^=/ml.$$

(3) A set of at least 10 working standards in the range of 5 to 50 µg/ml $SO_4^=$ shall be prepared by dilution of the gravimetric

standard. (Dilutions of a working standard to give another working standard are not acceptable.) Each working standard should be about 100 ml volume. Glassware shall be cleaned in accordance with paragraph (b)(1)(iii) of this section prior to use in preparing these standards.

(4) The integrator response (ie., area under the chart recorder curve) of the analyzing system shall be determined for each of these standards. If these standards are retained for future linearity determinations, they shall be stored in polypropylene bottles which have been cleaned with dilute nitric acid, then rinsed and checked in accordance with (b)(1)(iii) of this section.

(5) The upper limit of the linear range of the analyzer shall be determined by graphical or mathematical techniques. This upper limit is, to a great extent, affected by sample loop size (0.5 ml is currently used) and spectrophotometer design.

(6) Determination of the linear range shall be performed each time the system is changed in any way that could affect the linear range. For example, changing column volume or sample loop size would affect the linear range.

(c) Preparation of calibration standards.

(1) At least 3 calibration standards shall be used in routine analysis.

(2) Each standard shall be prepared gravimetrically by using the method of paragraphs (b)(1) and (2) of this section.

(3) The calibration standards shall have nominal concentrations of 10, 50 and 90% of the upper limit of the linear range determined in (b) of this section.

(4) The calibration standards shall be stored in tightly capped polypropylene containers.

(5) New calibration standards shall be prepared whenever a new batch of 60/40 IPA is prepared.

(6)(i) New calibration standards shall be prepared at least weekly, or

(ii) at least weekly a new gravimetric standard (between 50% and 90% of the linear range) shall be prepared and analyzed. If this standard checks within 4% of the calibration curve, preparation of a new set of standards is not required.

NOTE: After completing the construction and calibration of the sampling and analytical components, it is desirable to test

the entire system for proper operation. An appropriate test consists of injecting a known amount of sulfuric acid into the system and then performing a sulfur balance from the analysis results. In this procedure, the use of a representative injection technique is critical. EPA is currently working to develop an adequate sulfuric acid injection test, but a procedure has not been sufficiently defined at the present time.]

§86.127-79 Test procedures, overview.

The procedures described in this and subsequent sections are used to determine the conformity of vehicles with the standards set forth in Subpart A for light duty vehicles and light duty trucks.

(a) The overall test consists of prescribed sequences of fueling, parking and operating conditions. [Vehicles are tested for any or all of the following emissions:

(i) gaseous exhaust HC, CO, NOx, CO_2.

(ii) exhaust sulfuric acid.

(iii) evaporative HC.]

(b) The [gaseous] exhaust emission test is designed to determine hydrocarbon, carbon monoxide, and oxides of nitrogen mass emissions while simulating an average trip in an urban area of 7.5 miles (12.1 km). The test consists of engine startups and vehicle operation on a chassis dynamometer, through a specified [urban] driving schedule. A proportional part of the diluted exhaust is collected continuously for subsequent analysis, using a constant volume (variable dilution) sampler. (Diesel dilute exhaust is continuously analyzed for hydrocarbons using a heated sample line and analyzer).

[(c) The sulfuric acid exhaust emission test is designed to determine sulfuric acid mass emission while simulating a 13.5 mile (21.7 km) trip on a congested freeway. The engine is warm and idling when the test begins. The vehicle is operated on a chassis dynamometer through a specified congested freeway driving schedule. A proportional part of the diluted exhaust is collected continuously on a filter using a dilution tunnel and constant volume (variable dilution) sampler. The filter is analyzed afterwards by a wet chemistry technique.]

(d) The evaporative emission test (gasoline fueled vehicles only) is designed to determine hydrocarbon evaporative emissions as a consequence of diurnal temperature fluctuation, urban driving, and hot soaks during parking. It is associated with a series of events representative of a motor vehicle's operation, which result in hydrocarbon vapor losses. The test procedure is designed to measure:

(1) Diurnal breathing losses resulting from daily temperature changes, measured by the enclosure technique;

(2) Running losses from suspected sources (if indicated by engineering analysis or vehicle inspection) resulting from a simulated trip on a chassis dynamometer, measured by carbon traps; and

(3) Hot soak losses which result when the vehicle is parked and the hot engine is turned off, measured by the enclosure technique.

(e) Except in cases of component malfunction or failure, all emission control systems installed on or incorporated in a new motor vehicle shall be functioning during all procedures in this subpart. Maintenance to correct component malfunction or failure shall be authorized in accordance with §86.077.

§86.128-79 Transmissions.

(a) All test conditions shall be run with automatic and automatic stick shift transmissions in "Drive" (highest gear); manual transmissions shall be run in highest gear, except as noted. Automatic stick-shift transmissions may be shifted as manual transmissions if requested by the manufacturer.

(b) Cars equipped with free-wheeling or overdrive units shall be tested with these units locked out of operation.

(c) Idle modes shall be run with automatic transmissions in "Drive" and the wheels braked, manual transmissions shall be in gear with the clutch disengaged; except first idle, see §§86.136 and 86.137.

(d) The vehicle shall be driven with minimum accelerator pedal movement to maintain the desired speed.

(e) Acceleration modes shall be driven smoothly. Automatic transmissions shall shift automatically through the normal sequence of gears; manual transmissions shall be shifted as recommended by the manufacturer with the operator releasing the accelerator pedal during each shift and accomplishing the shift with minimum time. If the vehicle cannot accelerate at the specified rate, the vehicle shall be operated with the accelerator pedal fully depressed

until the vehicle speed reaches the value prescribed for that time in the driving schedule.

(f) The deceleration modes shall be run in gear using brakes or accelerator pedal as necessary to maintain the desired speed.

[(1 On the Urban Dynamometer Driving Schedule,] manual transmission vehicles shall have the clutch engaged and shall not change gears from the previous mode. For those modes which decelerate to zero, manual transmission clutches shall be depressed when the speed drops below 15 mph (24.14 kph), when engine roughness is evident, or when engine stalling is imminent.

[(2) On the Congested Freeway Dynamometer Driving Schedule, manual transmission vehicles shall have the clutch engaged and shall not change gears from the previous mode except as noted on the speed time listing in Appendix IA, when engine roughness is evident, or when engine stalling is imminent.]

(g) Manual transmissions [shall] be down shifted at the beginning of or during a power mode if recommended by the manufacturer or if the engine obviously is lugging.

(h) If shift speeds are not recommended by the manufacturer, manual transmission vehicles shall be shifted [as follows]:

[(1) Urban driving schedule - Shift] from first to second gear at 15 mph (24.14 kph), from second to third gear at 25 mph (40.23 kph), and, if so equipped, from third to fourth gear at 40 mph (64.37 kph).

[(2) Congested freeway driving schedule - Shift speeds are noted on the speed time listing in Appendix VIII.]

(3) Fifth gear, if so equipped, may be used at the manufacturers option.

(i) If a four - or five - speed manual transmission has a first gear ratio in excess of 5:1, follow the procedure for three - or four - speed vehicles as if the first gear did not exist.

§86.130-79 Test sequence, general requirements.

The test sequence shown in Figure [B79-5] shows the steps encountered as the test vehicle undergoes the procedures subsequently described to determine conformity with the standards set forth. Ambient temperature levels encountered by the test vehicle throughout the test sequence shall not be less than 20°C (68°F) nor more than 30°C (86°F). The vehicle shall be approximately level during all phases of the test sequence to prevent abnormal fuel distribution.

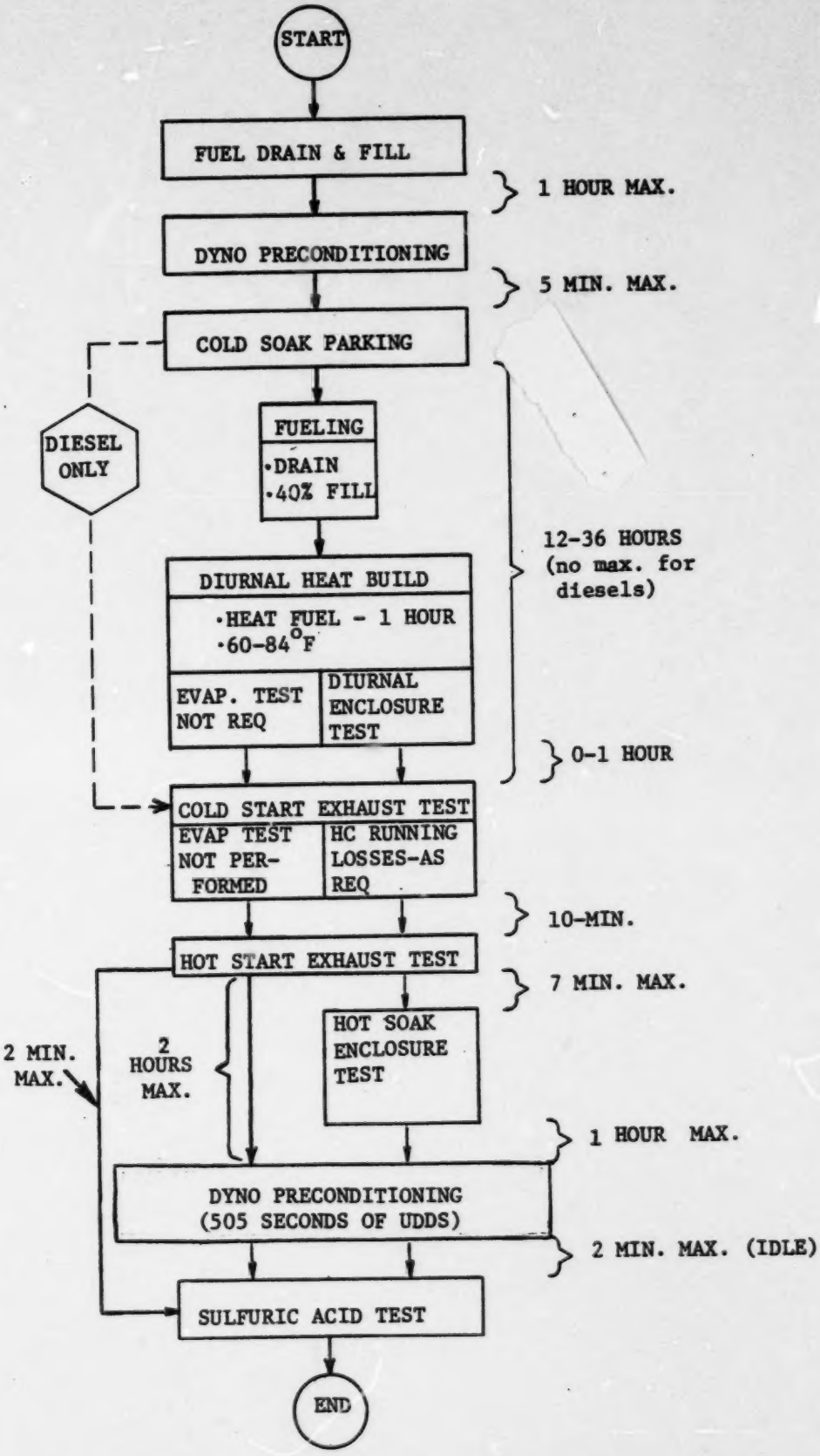

FIGURE B79-5 TEST SEQUENCE

§86.132-79 Vehicle preconditioning.

(a) The vehicle shall be moved to the test area and the following operations performed:

(1) The fuel tank(s) shall be drained through the provided fuel tank drain(s) and filled to the prescribed "tank fuel volume" with the specified test fuel, §86.113. For the above operations the evaporative emission control system shall neither be abnormally purged nor abnormally loaded.

(2) Within one hour of being fueled the vehicle shall be placed, either by being driven or pushed, on a dynamometer and operated through one Urban Dynamometer Driving Schedule test procedure, see §86.115 and Appendix I. A gasoline fueled test vehicle may not be used to set dynamometer horsepower.

(3) For those unusual circumstances where additional preconditioning is desired by the manufacturer, such preconditioning may be allowed with the advance approval of the Administrator. The Administrator may also choose to conduct or require the conduct of additional preconditioning to insure that the evaporative emission control system is stabilized. The additional preconditioning shall consist of an initial one hour minimum soak and, one, two or three driving cycles of the UDDS, as described in (a)(2), each followed by a soak of at least one hour with engine off, engine

compartment cover closed and cooling fan off. The vehicle may be driven off the dynamometer following each UDDS for the soak period.

(b) Within five minutes of completion of preconditioning the vehicle shall be driven off the dynamometer and parked. The vehicle shall be stored for not less than 12 hours nor for more than 36 hours (except diesel fueled vehicles which have no maximum time limitation) prior to the cold start exhaust test. (Gasoline fueled vehicles undergo a one hour diurnal heat build prior to the cold start exhaust test. A wait of up to one hour is permitted between the end of the diurnal heat build and the beginning of the cold start exhaust test. See §86.130 and Figure B79-5.)

(c) Vehicles to be tested for evaporative [and sulfuric acid emissions shall be processed in accordance with procedures in §§86.133 through 86.139. Vehicles to be tested for evaporative but not sulfuric acid emissions shall be processed according to §§86.133 through 86.138. Vehicles to be tested for sulfuric acid but not evaporative emissions shall be processed in accordance to §§86.133 through 86.137 and §86.139. Vehicles to be tested for exhaust emissions only shall be processed according to §§86.133 through 86.137.]

§86.135-79 Dynamometer procedure.

[(a) Dynamometer runs.]

(1) The [urban] dynamometer run consists of two tests, a "cold" start test after a minimum 12-hour and a maximum 36 hour soak according to the provisions of §86.132 and §86.133 and a "hot" start test following the "cold" start by 10 minutes. Engine startup (with all accessories turned off), operation over the driving schedule, and engine shutdown make a complete cold start test. Engine startup and operation over the first 505 seconds of the driving schedule complete the hot start test. The exhaust emissions are diluted with ambient air and a continuously proportional sample is collected for analysis during each phase. The composite samples collected in bags are analyzed for hydrocarbons (except diesel hydrocarbons which are analyzed continuously), carbon monoxide, carbon dioxide, and oxides of nitrogen. A parallel sample of the dilution air is similarly analyzed for hydrocarbon, carbon monoxide, and oxides of nitrogen.

[(2) The congested freeway dynamometer run consists of a single test which follows the hot-soak evaporative test, or when no evaporative test is conducted follows the exhaust test. Between vehicle preconditioning and start of the sulfate test, the vehicle engine is not shut down, but remains idling. The vehicle exhaust is diluted with ambient air and a proportional part of the diluted exhaust is collected on a filter. The CVS-

dilution tunnel sampling equipment shown in figure B79-1 or B79-2 is used. The material trapped on the filter is analyzed for sulfuric acid. (A parallel sample of the dilution air may also be analyzed for sulfuric acid for the purpose of providing background sulfate correction; in which case CO_2 in the dilute exhaust must also be measured.)]

(b) During dynamometer operation, a fixed speed cooling fan shall be positioned so as to direct cooling air to the vehicle in an appropriate manner with the engine compartment cover open. In the case of vehicles with front engine compartments, the fan shall be squarely positioned within 12 inches of the vehicle. In the case of vehicles with rear engine compartments (or if special designs make the above impractical), the cooling fan shall be placed in a position to provide sufficient air to maintain vehicle cooling. [The linear velocity of the air at the front of the vehicle shall not exceed the following velocities:

	Maximum Air Volume		Maximum Air Velocity	
Driving Schedule	m^3/s	(CFM)	m/s	(ft/s)
Urban	2.5	(5300)	9.4	(31)
Congested freeway	11.8	(25,000)	15.8	(52)

]

If, however, the manufacturer can show that during field operation the vehicle receives additional cooling, and that such additional cooling is needed to provide a representative test, the fan capacity may be increased, additional fans used, or a different fan configuration may be used if approved in advance by the Administrator.

(c) The vehicle speed as measured from the dynamometer rolls shall be used. A speed vs. time recording, as evidence of dynamometer test validity, shall be supplied on request of the Administrator.

(d) Practice runs over the prescribed driving schedule may be performed at test points, provided an emission sample is not taken, for the purpose of finding the minimum throttle action to maintain the proper speed-time relationship, or to permit sampling system adjustments.

NOTE: When using two-roll dynamometers a truer speed-time trace may be obtained by minimizing the rocking of the vehicle in the rolls. The rocking of the vehicle changes the tire rolling radius on each roll. This rocking may be minimized by restraining the vehicle horizontally (or nearly so) by using a cable and winch.

(e) The drive wheel tires may be inflated up to a gauge pressure of 45 psi (310 kPa) in order to prevent tire damage. The drive wheel tire pressure shall be reported with the test results.

(f) If the dynamometer has not been operated during the 2 hour period immediately preceding the test it shall be warmed up for 15 minutes by operating at 30 mph (48 km/hr) using a non-test vehicle or as recommended by the dynamometer manufacturer.

(g) If the dynamometer horsepower must be adjusted manually, it shall be set within 1 hour prior to the exhaust emissions test phase. The test vehicle shall not be used to make this adjustment. Dynamometers using automatic control of preselectable power settings may be set anytime prior to the beginning of the emissions test.

§86.137-79 Dynamometer test run, gaseous emissions.

(a) The vehicle shall be allowed to stand with the engine turned off for a period of not less than 12 hours or more than 36 hours before the cold start exhaust emission test. The cold start exhaust test shall follow the diurnal breathing loss test by not more than 1 hour. The vehicle shall be stored prior to the emission test in such a manner that precipitation (e.g. rain or dew) does not occur on the vehicle. The complete dynamometer test consists of a cold start drive of 7.5 miles (12.1 km) and simulates a hot start drive of 7.5 miles (12.1 km). The vehicle is allowed to stand on the dynamometer during the 10 minute time period between the cold and hot start tests. The cold start test is divided into two periods. The first period, representing the cold start "transient" phase, terminates at the end of the deceleration which is scheduled to occur at 505 seconds of the driving schedule. The second period, representing the "stabilized" phase, consists of the remainder of the driving schedule including engine shutdown. The hot start test similarly consists of two periods. The period, representing the hot start "transient" phase, terminates at the same point in the driving schedule as the first period of the cold start test. The second period of the hot start test, "stabilized" phase, is assumed to be identical to the second period of the cold start test. Therefore, the hot start test terminates after the first period (505 seconds) is run.

(b) The following steps shall be taken for each test:

(1) Place drive wheels of vehicle on dynamometer without starting engine.

(2) Open the vehicle engine compartment cover and position the cooling fan.

(3) With the sample selector valves in the "standby" position connect evacuated sample collection bags to the two dilute exhaust and two dilution air sample collection systems.

(4) Start the Constant Volume Sampler (if not already on), the sample pumps, the temperature recorder, the vehicle cooling fan and the heated hydrocarbon analysis recorder (diesel only). (The heat exchanger of the constant volume sampler, if used, diesel hydrocarbon analyzer continuous sample line and filter (if applicable) should be preheated to their respective operating temperatures before the test begins.)

(5) Adjust the sample flow rates to the desired flow rate (minimum of 10 cfh, 0.28 m^3/hr) and set the gas flow measuring devices to zero.

NOTE: CFV-CVS sample flowrate is fixed by the venturi design.

(6) Attach the flexible exhaust tube to the vehicle tailpipe(s).

(7) Start the gas flow measuring device, position the sample selector valves to direct the sample flow into the "transient" exhaust sample bag and the "transient" dilution air sample bag, (turn on the diesel hydrocarbon analyzer system integrator and mark the recorder chart, if applicable) and start cranking the engine.

(8) Fifteen seconds after the engine starts, place the transmission in gear.

(9) Twenty seconds after the engine starts, begin the initial vehicle acceleration of the driving schedule.

(10) Operate the vehicle according to the Urban Dynamometer Driving Schedule (§86.115).

(11) At the end of the deceleration which is scheduled to occur at 505 seconds, simultaneously switch the sample flows from the "transient" bags to the "stabilized" bags, switch off gas flow measuring device No. 1 (and the diesel hydrocarbon integrator No. 1, mark the diesel hydrocarbon recorder chart) and start gas flow measuring device No. 2 (and diesel hydrocarbon integrator No. 2). As soon as possible, and in no case longer than 20

minutes after the end of this portion of the test, transfer the "transient" exhaust and dilution air sample bags, to the analytical system and process the samples according to §86.140.

(12) Turn the engine off 2 seconds after the end of the last deceleration (at 1,369 seconds).

(13) Five seconds after the engine stops running, simultaneously turn off gas flow measuring device No. 2 (and the diesel hydrocarbon integrator No. 2, mark the hydrocarbon recorder chart, if applicable) and position the sample selector valves to the "standby" position. As soon as possible, transfer the "stabilized" exhaust and dilution air samples to the analytical system and process the samples according to §86.140 obtaining a stablized reading of the exhaust sample on all analyzers within 20 minutes of the end of the sample collection phase of the test.

(14) Immediately after the end of the sample period turn off the cooling fan and close the engine compartment cover.

(15) Turn off the CVS or disconnect the exhaust tube from the tailpipe of the vehicle.

(16) Repeat the steps in paragraph (b)(2) through (10) of this section for the hot start test, except only one evacuated

sample bag is required for sampling exhaust gas and one for dilution air. The step in paragraph (b)(7) of this section shall begin between 9 and 11 minutes after the end of the sample period for the cold start test.

(17) At the end of the deceleration which is scheduled to occur at 505 seconds, simultaneously turn off gas flow measuring device No. 1 (and diesel hydrocarbon integrator No. 1, mark the diesel hydrocarbon recorder chart, if applicable) and position the sample selector valve to the "standby" position. (Engine shutdown is not part of the hot start test sample period.)

(18) As soon as possible, and in no case longer than 20 minutes after the end of this portion of the test transfer the hot start "transient" exhaust and dilution air sample bags, to the analytical system and process the samples according to §86.140.

[(19) Vehicles to be tested for sulfuric acid emission but not evaporative emissions, will proceed according to §86.139. All other vehicles will proceed as follows:

(i) Disconnect the exhaust tube from the vehicle tail-pipe(s) and drive vehicle from dynamometer.

(ii) The constant volume sampler may be turned off, if desired.

(20) Vehicles to be tested for evaporative emissions will proceed according to §86.138. For vehicles not to be tested for either evaporative or sulfuric acid emissions, this completes the test sequence.]

§86.138-79 Hot soak test.

The hot soak evaporative emission test shall be conducted immediately following the hot transient exhaust emission test.

(a) Prior to the completion of the hot start transient exhaust emission sampling period, the evaporative emission enclosure shall be purged for several minutes.

(b) The FID hydrocarbon analyzer shall be zeroed and spanned immediately prior to the test.

(c) If not already on, the evaporative enclosure mixing fan shall be turned on at this time.

(d) Upon completion of the hot transient exhaust emission sampling period, the vehicle engine compartment cover shall be closed, the cooling fan shall be moved, the vehicle shall be disconnected from the dynamometer and exhaust sampling system, and then driven at minimum throttle to the vehicle entrance of the enclosure.

(e) The vehicle's engine must be stopped before any part of the vehicle enters the enclosure. The vehicle may be pushed or coasted into the enclosure.

(f) The test vehicle windows and luggage compartments shall be opened, if not already open.

(g) The temperature recording system shall be started and the time of engine shut off shall be noted on the evaporative emission hydrocarbon data recording system.

(h) The enclosure doors shall be closed and sealed within two minutes of engine shutdown and within seven minutes after the end of the exhaust test.

(i) The 60 $\pm$ 0.5 minute hot soak begins when the enclosure doors are sealed. The enclosure atmosphere shall be analyzed and recorded. This is the initial (time = 0 minutes) hydrocarbon concentration, C_{HCi}, for use in calculating evaporative losses, see §86.143.

(j) The test vehicle shall be permitted to soak for a period of one hour in the enclosure.

(k) The FID hydrocarbon analyzer shall be zeroed and spanned immediately prior to the end of the test.

(l) At the end of the 60 $\pm$ 0.5 minute test period, again analyze the enclosure atmosphere and record time. This is the final (time = 60 minutes) hydrocarbon concentration, C_{HCf}, for use in calculating evaporative losses, see §86.143. This operation completes the evaporative emission measurement procedure.

[§86.139-79 Dynamometer test run, sulfate emission.

(a) The following steps shall be taken for vehicle immediate preconditioning:

(1) If the vehicle has been tested for hot soak evaporative emissions, the vehicle may be driven from the SHED onto the dynamometer. The correct inertia weight is set and then the correct dynamometer power is set while operating the vehicle at a constant speed of 50 mph for no longer than 1 minute. The vehicle shall then be preconditioned on the dynamometer. This preconditioning shall begin within 1 hour after the end of the hot soak test and shall consist of the first 505 seconds of the UDDS.

(2) If the vehicle is not to be tested for hot soak evaporative emissions, if the same dynamometer is to be used for sulfuric acid testing as gaseous exhaust testing, and if the sulfuric acid test is to immediately follow the gaseous exhaust testing, then vehicle operation during the gaseous emission test can serve as preconditioning for the sulfuric acid test. In this case the sulfuric acid test shall begin within 2 minutes after the end of the gaseous exhaust test, while the vehicle is at idle (Fig. B79-5). If the sulfuric acid test is not to begin within 2 minutes of the gaseous exhaust test, then dynamometer setting and vehicle preconditioning shall be conducted as specified in (a)(3) which follows.

(3) If the vehicle is not to be tested for hot soak evaporative emissions and if a different dynamometer is to be used for sulfuric acid testing than for gaseous exhaust testing, then the vehicle may be driven to the new location provided engine operating time is not greater than 2 minutes and the new location is not farther than 1 mile. The correct inertia weight is set and then the dynamometer power is set while operating the vehicle at a constant speed of 50 mph for no longer than one minute. The vehicle shall then be preconditioned on the dynamometer. This preconditioning shall begin within 2 hours after the end of the gaseous emission sampling period and shall consist of the first 505 seconds of the UDDS.

(b) The following steps shall be taken for the test:

(1) Before the start of the idle period:

(i) Weigh the sulfuric acid collection filter on a balance which has a precision of at least 0.01 mg, and record this weight. Place the filter in a covered petri dish or in a filter holder which is capped on both ends. (This may be done several hours prior to the test). Filter weighing is not required for non-catalyst vehicles. The purpose of filter weighing is to estimate the $SO_4^=$ content of the used filters. For some vehicles (such as non-catalyst equipped, diesels and stratified charge) filter weight cannot be used to estimate $SO_4^=$ content.

CAUTION: The filter must be handled carefully and touched only with forceps. Also, static charges on the filter may cause an error in the filter weight. Techniques, such as exposure of the filter to a radioactive source, are available to eliminate this interference.

(ii) Start the CVS (if not already on) and the temperature recorder.

(iii) Carefully place the sulfuric acid collection filter into the filter holder if this has not been done in paragraph (b)(1)(i) of this section. The sample pump may be operated momentarily (providing vehicle exhaust is not sampled) to assist in filter positioning and to preset the flow rate. Operation of the sample pump should not exceed 1 minute and the flow through the filter shall not be included in the total flow during the test.

(2) During the two minute idle period:

(i) Place the uncapped filter holder into the sample train.

(ii) Read or reset the gas meter to zero.

(iii) Connect the vehicle tailpipe to the dilution tunnel (if not already connected).

(iv) Reset and enable the roll revolution counter.

(v) Start the vehicle cooling fan(s).

(3) At the start of the test:

(i) Simultaneously start the CVS counter and the exhaust sample train. Also start the dilution air sampling train if background sulfuric acid is to be measured.

(ii) Place the transmission in gear.

(iii) Ten seconds after the sample train is started begin the initial vehicle acceleration of the Congested Freeway Dynamometer Driving Schedule.

(4) During the test:

(i) Adjust the flow rate through the dilute exhaust sampling filter to maintain a constant value within $\pm$ 10% of isokinetic flow. Flow through the dilution air sample line (if used) should be approximately the same as through the dilute exhaust sample line.

(ii) Record the average temperature(s) and pressure(s) at the gas meter inlet(s).

(iii) If sample flow can not be maintained because of high particulate loading on the filter the test shall be terminated. The test shall be re-run using a smaller diameter probe, 0.95 cm (0.375 in) minimum, or larger diameter filter, or both, and appropriate flow rate to maintain isokinetic sampling.

(iv) Eight seconds after the end of deceleration scheduled to occur at 1390 seconds, simultaneously stop the CVS counter and the sample flows. The vehicle engine may then be stopped.

(5) Immediately after the test:

(i) Carefully remove each filter from its filter holder and place it into a petri dish for subsequent analysis. Cover the petri dish. The top surface of the filter should not be permitted to touch the petri dish during this or subsequent handling.

NOTE: Should the top surface of the filter contact the petri dish the petri dish shall be ammoniated, then rinsed with 10 ml of 60/40 IPA solvent. The resultant solution shall be analyzed for sulfate using the procedure of §86.141. The mass of sulfate determined by this analysis shall be added to the mass of sulfate found on the filter giving total sulfate mass found during the test, S_e (defined in §86.145-79(a)(7)).

(ii) Record the CVS counter reading and the gas meter reading(s).

(iii) Record the roll or shaft revolutions or measured distance.

(6) This completes the test sequence.

§86.141-79 Exhaust sample analysis, sulfuric acid emission.

Use of the automated barium chloranilate system, the calibration procedure for which is given in §86.125, is summarized below.

(a) Filters shall be prepared as follows:

(1) The filter is received for analysis in a petri dish, or it is removed from the filter holder and placed into a petri dish when it is received for analysis.

(2) Within one hour following the end of the sulfate test, place the opened petri dish containing the filter into a bell jar or desiccator and expose it to concentrated ammonium hydroxide (NH_4OH) vapors for at least 30 minutes. The sulfuric acid (H_2SO_4) is thus converted to ammonium sulfate ($(NH_4)_2SO_4$) and water. The water quickly evaporates from the filter.

(i) A vacuum system is recommended for drawing ambient air through a bubbler containing concentrated NH_4OH and into the desiccator. A flow rate of approximately 1 l/min is sufficient. The concentration of the NH_4OH solution should be checked frequently because it looses strength with use. A strip of litmus paper inside the desiccator and visible to the outside has been found to be a satisfactory indicator of the strength of the NH_4OH vapor.

(ii) A column of sodium acid phosphate (NaH_2PO_4) or an equivalent compound is recommended between the desiccator and the vacuum pump to remove the NH_4OH and protect the pump.

WARNING: Avoid human exposure to the concentrated NH_4OH vapor.

(3) Weigh the ammoniated filter on a balance which has a precision of at least 0.01 mg, and record the weight. The tare weight was obtained earlier (§86.139-79(b)(1)(i). For catalyst equipped vehicles the net weight gained can be assumed to be ammonium sulfate. Approximately 73% of the net weight can be assumed to be $SO_4^=$ for estimating the dilution required. Filter weighing is not required for non-catalyst vehicles.

(4) Carefully place each filter into a 20 to 50 ml polypropylene bottle. The filters can be stored this way for several days if required.

(b) Integrity of the 60/40 IPA solvent shall be checked as follows:

(1) Load the sampler (Fig. B79-3) with a high concentration standard and at least two blanks. Sample vials must be kept covered.

(2) Observe the integrator responses.

(3) The response of the last blank should be less than 0.5% of the response of the standard. If the blank response is greater than 0.5%, a water imbalance in the 60/40 IPA solvent or a handling problem exists. The cause of the high blank response shall be eliminated and the blanks re-run before beginning sample preparation and analysis.

(c) Samples shall be prepared as follows:

CAUTION: When preparing samples care must be taken to avoid evaporation of alcohol from the 60/40 IPA solvent. All containers of this solvent should be kept tightly capped whenever possible. Also, measurement and transfer of solvent to the filter shall be done with a pipette which meets NBS Class A accuracy designation or equivalent.

(1)(i) To prepare samples for which the sulfate content can be estimated (paragraph (b)(3) of this section), add sufficient 60/40 IPA (but no less than 10 ml) to result in a concentration which will give a high midscale response on the analyzer.

Example: If the net weight gain is 500 µg, then 73% or approximately 365 µg is $SO_4^=$. If the upper limit of the linear range as determined in the calibration procedure (§86.125) is 30

µg/ml, then dilute the sample to obtain approximately 20 µg/ml response.

$$\frac{365\ \mu g}{20\ \mu g/ml} \simeq 18\ ml$$

Add 20 ml of 60/40 IPA using a 20 ml NBS Class A pipette.

(ii) To prepare samples for which the sulfate content cannot be estimated, use 10 ml of 60/40 IPA or twice the minimum volume required by the analytical system for a single analysis, whichever is greater.

(2) Cap bottles tightly and shake vigorously. Use of a wrist action shaker for 30 minutes or use of a vortex mixer three times at 10 minute intervals for one minute each time are satisfactory mixing methods.

(3) Samples are now ready for analysis and shall be analyzed within 2 hours of preparation.

(d) Samples shall be analyzed as follows:

(1) Load the sampler (Fig. B79-3) with several blank solvent solutions followed by 2 high concentration (90%) standards. Sample vials must be kept covered.

(2) Observe the integrator responses.

(3) The response of the blanks should be less than 0.5% of the response of the 90% standard. If the blank response is greater than 0.5%, a water imbalance in the 60/40 IPA solvent or a handling problem exists. The cause of the high blank response shall be eliminated and the blanks re-run before proceeding with sample analysis.

(4) Load the sampler with several vials of the 90% standard. Observe the response of those repetitive standards. The first one or two responses tend to be low since they are "conditioning" the columns. Once two consecutive responses are the same (within 2%), the columns are conditioned and the last two responses can be used as the 90% standard calibration points.

(5) Load the sampler with two vials of the middle concentration (50%) standard and two vials of the lowest concentration (10%) standard, and record the integrator responses. The difference between the two responses of either standard should be less than 2% or less than 1% of the response of the high concentration standard, whichever is larger.

(6) If repetitive responses of the same standard do not agree within the above tolerances, then eliminate the cause for the discrepancy. Two common problems are:

(i) Insufficient purging of the sample loop between standards, in which case a blank shculd be used between standards.

(ii) Improper handling of standards (e.g., not keeping vials tightly covered).

(7) Using the concentration and area response data from each of the gravimetric standards, perform a linear least squares regression of the form:

$$\text{concentration} = (\text{area count}) \times A_1 + A_0$$

NOTE: Other curve forms are also acceptable if approved by the Administrator.

(8) Determine the percent deviation of each standard from the calculated value.

(9) Run standards more than once if desired; however, give each standard determination equal weight in the linear regression.

(10) If the deviation of any standard is more than 4% from the calculated linear regression value, determine and eliminate the cause of the discrepancy.

(11) Since at concentrations below the lowest standard the

shape of the true calibration curve is non-linear, and since it is desirable that the calibration curve pass through the origin, the calibration curve between zero and the lowest calibration standard is defined as a straight line between the origin and the point on the previously determined least squares line which is the gravimetrically determined concentration of the lowest standard.

(12) Load the sampler with samples, saving enough sample in each bottle for later dilution and re-running should it be needed. Place blanks between samples, if desired.

(13) Proceed with analysis.

(14) Run two vials of the 50% standard as specified in (d)(5) of this section at least once during each two hour period of operation. If these two determinations do not meet the requirements of paragraphs (d)(5) and (d)(11) of this section, run all three standards as specified in paragraphs (d)(1) through (d)(11) of this section. Also run the three standards after the last sample of a series has been run and whenever the system is restarted after a one hour or longer shutdown. Update the response curve each time the three standards are run. If the response curve when the standards are run has changed by more than 4% from the previous run, possible saturation of a cation exchange resin column is indicated. Determine and eliminate the cause for such a change in response, if possible. If the cause of the change

cannot be eliminated, re-run the three calibration standards and update the response curve. In addition, re-run samples run since the last calibration check; therefore, do not discard the portion of each sample remaining in the polypropylene bottles until the standard(s) have been re-run.

(15) If the response of any sample is greater than the response of the highest concentration standard used, dilute and re-run that sample.

(i) The dilution shall result in a sample which will give a midrange response.

(ii) The dilution shall be accomplished by transferring at least 2 ml of sample from the original sample bottle into a clean sample bottle. A measured amount of 60/40 IPA solvent is then immediately added to complete the dilution, and the bottle is capped and shaken.

(iii) Fixed volume pipettes which meet the National Bureau of Standards Class A designation shall be used.

(iv) The sulfate dilution factor, SDF, which is the ratio of amount of total dilute sample to amount of original sample transferred, shall be calculated.

(16) If the response of a dilute sample is greater than the response of the highest concentration standard used, then further dilute the sample for the purpose of obtaining an estimate of the dilution required to obtain a midrange response. Once the required dilution is known, dilute the original sample one time to obtain the sample for analysis.

(17) If the response of any sample is less than 5% of the highest standard used, the sample analysis is valid only if one of the following conditions were met:

(i) The original sample was prepared in 10 ml or less of 60/40 IPA solvent and not subsequently diluted; or

(ii) The volume of the original sample was no more than twice the minimum volume required for a single analysis, as determined by analytical system parameters.

If the response of any sample is less than 5% of the highest standard and neither of the above two conditions were met, the analysis is invalid. The vehicle must be rerun to obtain another sample.

NOTE: Because of the time and cost of re-running vehicles, it is acceptable for duplicate samples to be taken. It is not necessary to analyze both filters, if a valid analysis is made on

one. However, if both filters are analyzed, and if both analyses are valid, then the reported mass of sulfate on the filter must be the average of the two values.

(18) Determine the concentration of sulfate ion ($SO_4^=$) in the sample by using the area response of the integrator in the linear least squares regression equation determined in (7) above.

(19) Calculate the mass of sulfate on the filter (S_e) by multiplying this concentration by the sulfate dilution factor (SDF) calculated in (14) (iv) of this section, and by the original volume of solvent, ie.,

$$S_e = \text{concentration} \times \text{SDF} \times \text{original volume}$$

(20) Example:

The original sample was leached in 20 ml of 60/40 IPA and gave a response greater than the highest standard. The sample was diluted by pipetting 2.0 ml sample into a polypropylene bottle and then pipetting 4.0 ml of 60/40 IPA into the bottle. This solution was then run, and the concentration was found to be 25 µg/ml.

The sulfate dilution factor is:

$$\text{SDF} = \frac{4 + 2}{2} = 3$$

The mass of sulfate on the filter is:

$$S_e = 25\ \mu g/ml \times .3 \times 20\ ml = 1500\ \mu g]$$

§86.142-79 Records required.

The following information shall be recorded with respect to each test:

(a) Test number.

(b) System or device tested (brief description).

(c) Date and time of day for each part of the test schedule.

(d) Instrument operator.

(e) Driver or operator.

(f) Vehicle: Make - Vehicle identification number - Model year - Transmission type - Odometer reading - Engine displacement - Engine family - Evap. family - Idle rpm - Fuel system (fuel injection, nominal fuel tank(s) capacity, fuel tank(s) location, number of carburetors, number of carburetor barrels) - Inertia loading - Actual curb weight recorded at 0 miles - Actual road load at 50 mph (80 kph) and drive wheel tire pressure, as applicable.

(g) Indicated road load power absorption at 50 mph (80 kph) and dynamometer serial number. As an alternative to recording the dynamometer serial number, a reference to a vehicle test cell number may be used, with the advance approval of the Administrator, provided the test cell records show the pertinent information.

(h) All pertinent instrument information such as tuning - gain - serial number - detector number - range. As an alternative, a reference to a vehicle test cell number may be used, with the advance approval of the Administrator, provided test cell calibration records show the pertinent instrument information.

(i) Recorder charts: Identify zero, span, exhaust gas, and dilution air sample traces.

(j) Test cell barometric pressure, ambient temperature and humidity.

NOTE: A central laboratory barometer may be used, provided that individual test cell barometric pressures are shown to be within $\pm$ 0.1 percent of the barometric pressure at the central barometer location.

(k) Fuel temperatures, as prescribed.

(l) Pressure of the mixture of exhaust and dilution air entering the CVS metering device, the pressure increase across the device, and the temperature at the inlet. The temperature may be recorded continuously or digitally to determine temperature variations.

[(m) Pressure and temperature of the dilute exhaust mixture (and of the dilution air if sampled) at the inlet to the gas meter(s) used for sulfuric acid sampling.]

(n) The number of revolutions of the positive displacement pump accumulated during each test phase while exhaust samples are being collected. The number of standard cubic feet metered by a critical flow venturi during each test phase would be the equivalent record for a CFV-CVS.

(o) The humidity of the dilution air.

NOTE: If conditioning columns are not used (see 86.122 and 86.144) this measurement can be deleted. If the conditioning columns are used and the dilution air is taken from the test cell, the ambient humidity can be used for this measurement.

(p) Temperature set point of the heated sample line and heated hydrocarbon detector temperature control system (for diesel vehicles only).

[§86.145-79 Calculations; sulfate emission.

(a) The final reported test results for the mass of sulfate, measured as sulfuric acid, ($M_{H_2SO_4}$) in g/mile shall be computed by use of the following formula:

For gasoline powered vehicles:

$$M_{H_2SO_4} = \frac{1.021\ V_{mix}}{D \times 10^3} \times \frac{0.030}{W_s} \times \left[\frac{S_e}{V_e} - \frac{S_b}{V_b}\ (1-1/DF_a)\right]$$

or

$$M_{H_2SO_4} = \frac{3.063 \times 10^{-5}\ V_{mix}}{D \times W_s} \times \left[\frac{S_e}{V_e} - \frac{S_b}{V_b}\ (1-1/DF_a)\right]$$

For diesel powered vehicles:

$$M_{H_2SO_4} = \frac{1.021\ V_{mix}}{D \times 10^3} \times \frac{0.225}{W_s} \times \left[\frac{S_e}{V_e} - \frac{S_b}{V_b}\ (1-1/DF_a)\right]$$

or

$$M_{H_2SO_4} = \frac{2.297 \times 10^{-4}\ V_{mix}}{D \times W_s} \times \left[\frac{S_e}{V_e} - \frac{S_b}{V_b}\ (1-1/DF_a)\right]$$

where:

(1) V_{mix} = total dilute exhaust volume in liters per test, corrected to standard conditions (273°K (528°R) and 101.3 kPa (760 mm Hg)). V_{mix} is further defined in §86.144.

(2) $1.021 = MW_{H_2SO_4}/MW_{SO_4^=} = 98.08/96.06$

(3) D = measured number of miles per test.

(4) 10^3 = conversion from micrograms to milligrams.

(5) W_s = weight percent of sulfur in the test fuel.

(6) 0.030 = weight percent of sulfur in "standard" test gasoline.

(7) 0.225 = weight percent of sulfur in "standard" test diesel fuel.

(8) S_e = mass of $SO_4^=$ in the exhaust sample, micrograms.

(9) S_b = mass of $SO_4^=$ in the background sample, micrograms.

NOTE: (i) The background sulfate level at the EPA certification laboratory in Ann Arbor, Michigan is very low and the fluorocarbon filters do not contain sulfate. S_b will be assumed = 0 and background samples will not be taken with each exhaust sample.

(ii) Any manufacturer may make the same assumption without prior EPA approval.

(iii) If S_b is assumed = 0, then no background correction is made and CO_2 analysis is not required since DF_a no longer has an effect in determining $M_{H_2SO_4}$. The equation for gasoline powered vehicles then reduces to:

$$M_{H_2SO_4} = \frac{3.063 \times 10^{-5} \, V_{mix}}{D \times W_s} \times \frac{S_e}{V_e}$$

and for diesel powered vehicles is:

$$M_{H_2SO_4} = \frac{2.297 \times 10^{-4} \, V_{mix}}{D \times W_s} \times \frac{S_e}{V_e} .$$

(10) V_e = total volume of the dilute exhaust sample, liters at standard conditions.

$$V_e = \frac{K_m \times V_a \times (P_b + P_i) \times 273}{T_i \times 101.3}$$

where:

(i) K_m = dilute exhaust gas meter correction factor determined in §85.120.

(ii) V_a = actual dilute exhaust sample volume, liters.

(iii) P_b = barometric pressure, kPa.

(iv) P_i = pressure elevation above ambient measured at the inlet to the dilute exhaust sample gas meter, kPA. For most gas meters with unrestricted discharge P_i is negligible and can be assumed = 0.

(v) T_i = average temperature of the dilute exhaust sample at the inlet to the gas meter, °K.

(11) V_b = total volume of the background sample, liters at standard conditions. (V_b is not required if S_b is assumed = 0). It is calculated using the following formula:

$$V_b = \frac{K_{mb} \times V_{ab} \times (P_b + P_{ib}) \times 273}{T_{ib} \times 101.30}$$

where:

(i) K_{mb} = background gas meter correction factor determined in §85.120.

(ii) V_{ab} = actual background sample volume, liters.

(iii) P_b = barometric pressure, kPa.

(iv) P_{ib} = pressure elevation above ambient measured at the inlet to the background gas meter, kPa. For most gas meters with unrestricted discharge P_i is negligible and can be assumed = 0.

(v) T_{ib} = average temperature of the background sample at the inlet to the gas meter, °K.

(12) DF_a = approximate dilution factor. (DF_a is not required if Sb is assumed = 0).

$$DF_a = 13.4/CO_{2e}$$

where:

CO_{2e} is the concentration of CO_2 in the dilute exhaust sample, percent.

(b) The method of calculation to be used with other approved analytical procedures shall be approved in advance by the administrator. Glass fiber filters, often used with titration analytical procedures, usually contain a significant amount of sulfate. The amount contained can vary between filters in a batch and between batches. This means that simply subtracting the apparent sulfate found in a blank from the sample filter would probably result in a significant error. The method of solving this problem shall be

submitted to the Administrator, if glass fiber filters are used.]

APPENDIX VIII. EPA CONGESTED FREEWAY DYNAMOMETER DRIVING SCHEDULE

CYCLE DIST = 13.5 M
AVG SPEED = 34.8 MPH

PARENTHESIZED NUMBERS ARE SHIFT POINTS FOR MANUAL TRANSMISSIONS

SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR
0	0.0	(N)									
1	0.0		51	23.1		101	29.1		151	20.0	
2	0.0		52	24.5	(3)	102	28.7		152	20.0	
3	0.0		53	26.0		103	29.6		153	20.0	
4	0.0		54	27.6		104	30.3		154	19.6	
5	0.0	(1)	55	28.8		105	30.7		155	18.1	
6	0.0		56	29.6		106	30.0		156	15.7	
7	0.0		57	31.5		107	29.4		157	12.6	
8	0.0		58	32.5		108	27.8		158	10.3	
9	0.0		59	32.5		109	25.6		159	10.0	
10	0.0		60	31.2		110	25.0		160	9.5	
11	1.6		61	29.5		111	25.0		161	9.7	
12	4.5		62	29.1		112	24.8		162	10.0	
13	7.2		63	29.4		113	23.5		163	10.0	
14	9.7		64	30.8		114	23.0		164	10.0	
15	11.7		65	30.8		115	23.0		165	10.0	
16	13.3		66	30.8		116	23.6		166	10.5	
17	14.3		67	30.7		117	24.0		167	11.8	
18	14.9	(2)	68	30.7		118	25.0		168	13.6	
19	15.0		69	30.7		119	26.3		169	15.2	
20	15.7		70	29.7		120	27.3		170	16.8	
21	16.2		71	28.8		121	28.3		171	18.4	
22	15.4		72	27.2		122	29.3		172	19.6	
23	14.7		73	25.0		123	29.9		173	20.0	
24	14.7		74	22.5		124	30.4		174	20.0	
25	15.0		75	20.5		125	31.9		175	20.0	
26	15.0		76	19.3		126	32.4		176	20.0	
27	14.9		77	19.3		127	32.4		177	20.0	
28	13.9		78	19.5		128	32.0		178	19.5	
29	11.6		79	20.7		129	31.6		179	18.2	
30	10.0		80	21.3		130	31.0		180	16.2	
31	10.0		81	20.6		131	29.6		181	13.5	
32	10.0		82	20.1		132	28.9		182	10.9	
33	10.0		83	20.0		133	27.8		183	10.0	
34	10.7		84	20.0		134	26.3		184	10.0	
35	12.2		85	20.0		135	24.4		185	10.0	
36	13.5		86	20.0		136	22.1		186	10.0	
37	14.5		87	20.4		137	19.7		187	10.0	
38	14.8		88	21.1		138	17.4		188	10.0	
39	15.0		89	22.2		139	15.8		189	10.0	
40	15.2		90	23.4		140	15.0	(2)	190	10.1	
41	15.5		91	24.5		141	15.0		191	10.6	
42	15.0		92	25.5		142	15.0		192	11.6	
43	14.6		93	26.6		143	15.1		193	12.9	
44	14.6		94	27.7		144	16.1		194	14.0	
45	15.1		95	28.7		145	17.4		195	15.1	
46	15.8		96	29.5		146	18.6		196	16.2	
47	17.0		97	30.8		147	19.7		197	17.3	
48	18.6		98	30.6		148	20.0		198	18.4	
49	20.2		99	30.4		149	20.5		199	19.3	
50	21.6		100	29.9		150	20.0		200	19.9	

APPENDIX VIII. EPA CONGESTED FREEWAY DYNAMOMETER DRIVING SCHEDULE CONTINUED

SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR
201	20.0		251	56.0		301	46.0		351	51.1	
202	20.0		252	56.5		302	46.9		352	50.2	
203	20.0		253	56.5		303	48.0		353	49.8	
204	20.4		254	56.3		304	49.0		354	49.5	
205	21.4		255	56.0		305	49.9		355	49.5	
206	22.7		256	55.5		306	50.9		356	49.4	
207	24.6		257	55.2		307	51.9		357	49.6	
208	26.5		258	55.0		308	52.9		358	49.8	
209	28.2		259	54.8		309	53.8		359	50.0	
210	29.8	(3)	260	54.5		310	54.5		360	50.0	
211	31.5		261	54.2		311	54.9		361	50.2	
212	33.2		262	53.9		312	55.2		362	50.4	
213	34.9		263	54.0		313	55.0		363	50.3	
214	36.7		264	54.5		314	54.7		364	50.0	
215	38.2		265	54.5		315	54.3		365	49.7	
216	39.3		266	52.8		316	53.5		366	49.0	
217	40.0		267	50.4		317	53.0		367	47.8	
218	40.7	(4)	268	50.0		318	52.7		368	46.2	
219	41.0		269	49.6		319	53.3		369	44.0	
220	41.0		270	49.7		320	53.7		370	41.0	
221	41.0		271	50.0		321	53.7		371	38.0	
222	41.0		272	50.5		322	53.7		372	34.7	
223	40.0		273	50.3		323	54.5		373	31.4	
224	39.5		274	50.0		324	55.0		374	28.1	
225	39.3		275	49.3		325	55.0		375	24.8	(3)
226	39.6		276	47.8		326	55.2		376	21.8	
227	39.9		277	45.3		327	55.4		377	20.5	
228	40.0		278	42.3		328	55.5		378	20.0	
229	40.4		279	40.2		329	55.6		379	20.0	
230	41.2		280	40.0		330	55.6		380	20.0	
231	42.2		281	39.8		331	55.5		381	19.7	
232	43.6		282	39.7		332	55.4		382	18.5	
233	44.9		283	40.0		333	55.3		383	16.3	
234	46.2		284	40.2		334	55.3		384	13.2	
235	47.4		285	40.5		335	55.3		385	10.6	
236	48.6		286	42.4		336	55.6		386	10.0	(2)
237	49.8		287	44.2		337	55.9		387	10.0	
238	51.0		288	45.0		338	56.1		388	9.9	
239	52.3		289	45.5		339	56.1		389	9.6	
240	53.4		290	45.3		340	56.1		390	8.9	
241	54.3		291	45.0		341	56.1		391	7.9	
242	54.9		292	44.8		342	55.9		392	6.7	
243	55.3		293	44.5		343	55.6		393	5.6	
244	55.5		294	44.2		344	55.3		394	5.0	
245	55.5		295	44.0		345	55.1		395	4.8	
246	55.0		296	43.7		346	54.9		396	4.3	
247	55.0		297	43.5		347	54.7		397	4.0	(1)
248	55.0		298	44.1		348	54.1		398	4.5	
249	55.0		299	44.6		349	53.3		399	5.0	
250	55.0		300	45.3		350	52.2		400	5.0	

APPENDIX VIII. EPA CONGESTED FREEWAY DYNAMOMETER DRIVING SCHEDULE CONTINUED

SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR
401	5.0		451	7.8		501	9.4		551	32.3	
402	5.0		452	10.2		502	9.0		552	29.8	
403	5.4		453	12.1		503	7.1		553	26.8	
404	7.2		454	13.5		504	5.2		554	23.5	
405	9.0		455	14.5		505	5.0		555	20.2	
406	9.8		456	15.2	(2)	506	5.0		556	17.0	
407	9.7		457	15.0		507	5.0		557	14.0	
408	9.5		458	14.8		508	5.0		558	11.0	
409	9.2		459	14.8		509	5.0		559	9.8	(2)
410	9.3		460	14.8		510	5.0		560	9.6	
411	9.5		461	14.8		511	5.0		561	9.5	
412	9.9		462	15.0		512	5.0		562	9.5	
413	10.2		463	15.1		513	5.0		563	9.5	
414	10.4		464	15.2		514	4.4		564	9.5	
415	10.7		465	15.3		515	3.0		565	9.6	
416	12.1		466	15.3		516	1.0		566	9.9	
417	13.5		467	16.7		517	0.0		567	10.4	
418	14.7		468	18.8		518	0.0		568	11.4	
419	15.0	(2)	469	20.7		519	0.0		569	12.5	
420	15.0		470	22.6		520	0.0		570	13.5	
421	15.0		471	24.3	(3)	521	0.0		571	14.5	
422	15.0		472	24.5		522	0.0		572	15.2	
423	15.0		473	24.8		523	0.0		573	15.6	
424	15.1		474	25.0		524	0.0		574	15.8	
425	15.1		475	25.4		525	0.0		575	15.9	
426	15.1		476	26.0		526	0.0		576	15.6	
427	16.2		477	26.2		527	0.0		577	15.4	
428	17.6		478	26.1		528	0.5		578	15.2	
429	18.9		479	25.5		529	3.3		579	15.0	
430	19.9		480	25.2		530	6.3		580	14.3	
431	20.0		481	25.0		531	9.4		581	11.3	
432	20.0		482	24.3		532	12.7		582	8.0	
433	20.0		483	22.6		533	16.0		583	5.0	(1)
434	20.0		484	19.6		534	19.3	(2)	584	5.0	
435	19.8		485	16.4		535	22.6		585	5.0	
436	18.8		486	13.1		536	25.9		586	5.0	
437	16.8		487	10.2		537	29.0		587	5.0	
438	13.8		488	9.7		538	32.0		588	5.1	
439	10.5		489	9.4		539	34.5	(3)	589	6.1	
440	7.2		490	9.0		540	35.5		590	7.4	
441	4.5		491	8.8		541	35.3		591	8.6	
442	1.8		492	8.5		542	35.3		592	9.7	
443	0.0		493	8.1	(1)	543	35.3		593	10.0	
444	0.0		494	8.4		544	35.3		594	10.2	
445	0.0		495	8.8		545	35.2		595	10.1	
446	0.0	(1)	496	9.1		546	35.1		596	9.9	
447	0.0		497	9.0		547	35.0		597	9.8	
448	0.2		498	8.9		548	35.0		598	9.8	
449	2.2		499	8.9		549	34.8		599	9.9	
450	5.0		500	9.5		550	33.9		600	9.9	

APPENDIX VIII. EPA CONGESTED FREEWAY DYNAMOMETER DRIVING SCHEDULE CONTINUED

SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR
601	9.3		651	20.0		701	41.0		751	56.0	
602	8.0		652	19.8		702	42.4		752	56.0	
603	6.3		653	19.7		703	43.8		753	56.0	
604	5.0		654	19.7		704	44.9		754	55.5	
605	5.0		655	19.9		705	45.1		755	55.0	
606	5.2		656	19.9		706	45.4		756	55.0	
607	5.4		657	19.9		707	46.1		757	55.0	
608	5.1		658	20.0		708	46.7		758	55.0	
609	5.0		659	20.0		709	47.1		759	55.0	
610	5.9		660	20.8		710	47.1		760	55.0	
611	8.1		661	22.1		711	47.0		761	55.0	
612	10.2		662	24.0		712	46.3		762	55.0	
613	12.3		663	26.4		713	45.6		763	54.9	
614	14.3		664	28.7		714	45.2		764	54.5	
615	15.3	(2)	665	30.8		715	44.9		765	53.7	
616	16.0		666	32.9		716	45.0		766	52.6	
617	16.6		667	35.0	(3)	717	45.1		767	51.3	
618	16.5		668	37.1		718	45.4		768	50.3	
619	16.3		669	39.3		719	45.8		769	49.7	
620	16.1		670	41.5		720	46.8		770	49.5	
621	15.8		671	43.2		721	48.1		771	49.2	
622	15.2		672	44.4	(4)	722	49.2		772	48.9	
623	14.9		673	45.0		723	50.3		773	48.7	
624	15.1		674	45.3		724	51.5		774	48.5	
625	15.1		675	45.6		725	52.6		775	48.7	
626	14.9		676	45.8		726	53.7		776	48.8	
627	14.5		677	45.7		727	54.6		777	48.9	
628	13.6		678	45.1		728	55.0		778	50.0	
629	12.3		679	44.5		729	55.4		779	50.0	
630	10.8		680	44.0		730	55.8		780	50.0	
631	10.0		681	43.9		731	55.9		781	50.0	
632	10.1		682	44.1		732	56.5		782	50.0	
633	10.6		683	44.6		733	57.0		783	50.0	
634	10.9		684	45.0		734	57.0		784	50.0	
635	10.8		685	45.1		735	57.0		785	50.1	
636	9.9		686	45.0		736	56.7		786	50.2	
637	9.2		687	44.9		737	55.8		787	50.6	
638	9.7		688	44.3		738	54.9		788	51.2	
639	10.0		689	43.3		739	54.2		789	51.9	
640	10.4		690	41.9		740	53.8		790	52.5	
641	11.3		691	40.5		741	53.3		791	53.1	
642	12.7		692	40.0		742	52.8		792	53.8	
643	14.0		693	40.0		743	52.7		793	54.4	
644	15.2		694	40.0		744	53.0		794	54.8	
645	16.5		695	40.0		745	54.0		795	55.0	
646	17.8		696	40.0		746	55.0		796	55.5	
647	19.0		697	40.0		747	55.8		797	55.7	
648	19.8		698	40.0		748	55.9		798	56.0	
649	20.2		699	40.1		749	55.9		799	56.3	
650	20.1		700	40.3		750	56.0		800	56.5	

APPENDIX VIII. EPA CONGESTED FREEWAY DYNAMOMETER DRIVING SCHEDULE CONTINUED

SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR
801	56.2		851	45.2		901	19.7		951	18.[illegible]	
802	56.0		852	45.0		902	19.4		952	20.[illegible]	
803	55.5		853	45.0		903	19.7		953	22.3	
804	55.0		854	45.0		904	19.9		954	24.0	
805	55.0		855	45.0		905	20.0		955	25.7	
806	55.0		856	45.0		906	20.1		956	27.6	
807	54.5		857	45.0		907	20.9		957	29.0	(3)
808	54.7		858	45.0		908	21.9		958	29.9	
809	55.0		859	45.0		909	22.9		959	30.2	
810	55.5		860	45.0		910	23.9		960	30.5	
811	56.0		861	44.9		911	24.8		961	30.8	
812	56.5		862	44.5		912	25.3		962	30.8	
813	56.0		863	43.6		913	25.6		963	30.8	
814	55.5		864	42.3		914	25.4		964	30.6	
815	55.0		865	40.9		915	25.3		965	30.4	
816	55.0		866	40.0		916	25.2		966	30.2	
817	55.0		867	40.0		917	25.0		967	30.1	
818	55.0		868	39.7		918	25.0		968	30.2	
819	55.0		869	39.5		919	25.0		969	30.3	
820	55.0		870	39.2		920	24.8		970	31.2	
821	55.0		871	39.0		921	23.9		971	32.3	
822	55.0		872	39.4		922	22.3		972	33.2	
823	55.0		873	39.7		923	20.5		973	34.3	
824	54.7		874	40.0		924	20.0		974	34.9	
825	54.0		875	39.5		925	20.0		975	35.2	
826	52.9		876	37.7		926	20.0		976	35.5	
827	51.5		877	35.3		927	20.0		977	35.2	
828	50.3		878	35.0		928	20.0		978	35.1	
829	50.0		879	35.0		929	19.7		979	35.0	
830	49.7		880	35.0		930	19.5		980	35.0	
831	50.0		881	35.0		931	19.3		981	34.8	
832	51.3		882	35.0		932	19.1		982	34.2	
833	51.7		883	35.0		933	19.3		983	33.0	
834	52.0		884	35.0		934	19.5		984	31.5	
835	52.0		885	35.0		935	19.7		985	30.2	
836	51.7		886	34.8		936	19.9		986	30.0	
837	51.4		887	34.6		937	19.1		987	29.9	
838	51.2		888	33.0		938	17.5		988	29.8	
839	51.0		889	30.0		939	15.6		989	29.7	
840	50.7		890	27.5		940	15.0	(2)	990	29.6	
841	50.3		891	25.0	(3)	941	15.0		991	29.5	
842	50.0		892	25.0		942	14.7		992	29.4	
843	50.2		893	25.3		943	14.3		993	29.4	
844	50.5		894	25.5		944	14.0		994	29.8	
845	50.3		895	25.2		945	14.2		995	30.3	
846	50.1		896	24.9		946	14.5		996	30.9	
847	50.0		897	24.4		947	14.7		997	31.8	
848	49.7		898	23.1		948	15.0		998	32.9	
849	49.2		899	21.3		949	15.6		999	33.9	
850	47.3		900	20.0		950	16.9		1000	34.9	

APPENDIX VIII. EPA CONGESTED FREEWAY DYNAMOMETER DRIVING SCHEDULE CONTINUED

SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR
1001	35.9		1051	40.7		1101	55.5		1151	52.[illegible]	
1002	36.9		1052	40.8		1102	55.3		1152	53.[illegible]	
1003	37.9		1053	40.9		1103	55.1		1153	54.3	
1004	38.8		1054	40.9		1104	54.9		1154	54.8	
1005	39.5		1055	40.9		1105	54.7		1155	55.2	
1006	40.5		1056	40.9		1106	54.5		1156	55.5	
1007	41.0		1057	40.8		1107	54.[illegible]		1157	55.7	
1008	41.4		1058	40.8		1108	54.1		1158	55.9	
1009	41.6	(4)	1059	40.8		1109	53.9		1159	56.0	
1010	41.3		1060	40.8		1110	53.7		1160	56.1	
1011	41.0		1061	40.9		1111	53.5		1161	55.9	
1012	40.7		1062	42.5		1112	53.4		1162	55.8	
1013	40.5		1063	44.0		1113	53.3		1163	55.6	
1014	40.4		1064	45.0		1114	53.2		1164	55.4	
1015	40.3		1065	45.0		1115	53.3		1165	55.2	
1016	40.2		1066	45.5		1116	53.4		1166	55.1	
1017	41.9		1067	46.0		1117	53.6		1167	55.2	
1018	43.7		1068	46.3		1118	53.8		1168	55.3	
1019	45.0		1069	46.6		1119	54.0		1169	55.2	
1020	45.5		1070	46.3		1120	54.2		1170	55.1	
1021	46.0		1071	46.0		1121	54.3		1171	55.1	
1022	46.4		1072	45.7		1122	54.3		1172	55.0	
1023	46.3		1073	45.4		1123	54.4		1173	55.0	
1024	46.1		1074	45.1		1124	54.6		1174	55.0	
1025	45.9		1075	44.9		1125	54.8		1175	54.9	
1026	45.7		1076	44.7		1126	54.9		1176	54.7	
1027	45.5		1077	44.5		1127	55.0		1177	54.5	
1028	45.3		1078	44.3		1128	54.8		1178	54.6	
1029	45.1		1079	44.5		1129	54.1		1179	54.6	
1030	45.0		1080	44.6		1130	52.6		1180	54.7	
1031	44.9		1081	44.8		1131	50.8		1181	54.8	
1032	44.4		1082	45.0		1132	50.2		1182	54.9	
1033	43.6		1083	45.0		1133	50.0		1183	54.8	
1034	42.4		1084	45.1		1134	50.0		1184	54.7	
1035	40.8		1085	45.8		1135	50.0		1185	54.6	
1036	38.8		1086	47.0		1136	50.0		1186	54.7	
1037	36.9		1087	48.4		1137	50.0		1187	54.7	
1038	35.5		1088	49.6		1138	50.0		1188	54.8	
1039	35.0		1089	50.9		1139	50.0		1189	54.7	
1040	35.0		1090	52.1		1140	50.0		1190	54.6	
1041	35.0		1091	53.4		1141	50.0		1191	54.7	
1042	35.0		1092	54.4		1142	50.0		1192	55.0	
1043	35.0		1093	55.0		1143	50.0		1193	55.0	
1044	35.0		1094	55.5		1144	50.0		1194	55.0	
1045	35.1		1095	56.0		1145	50.0		1195	55.0	
1046	36.3		1096	56.3		1146	50.0		1196	54.9	
1047	37.7		1097	56.5		1147	50.3		1197	54.5	
1048	39.1		1098	56.3		1148	50.9		1198	53.8	
1049	40.0		1099	56.0		1149	51.6		1199	52.7	
1050	40.5		1100	55.8		1150	52.3		1200	51.4	

APPENDIX VIII. EPA CONGESTED FREEWAY DYNAMOMETER DRIVING SCHEDULE CONTINUED

SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR
1001	35.9		1051	40.7		1101	55.5		1151	52.[illegible]	
1002	36.9		1052	40.8		1102	55.3		1152	53.[illegible]	
1003	37.9		1053	40.9		1103	55.1		1153	54.3	
1004	38.8		1054	40.9		1104	54.9		1154	54.8	
1005	39.5		1055	40.9		1105	54.7		1155	55.2	
1006	40.5		1056	40.9		1106	54.5		1156	55.5	
1007	41.0		1057	40.8		1107	54.3		1157	55.7	
1008	41.4		1058	40.8		1108	54.1		1158	55.9	
1009	41.6	(4)	1059	40.8		1109	53.9		1159	56.0	
1010	41.3		1060	40.8		1110	53.7		1160	56.1	
1011	41.0		1061	40.9		1111	53.5		1161	55.9	
1012	40.7		1062	42.5		1112	53.4		1162	55.8	
1013	40.5		1063	44.0		1113	53.3		1163	55.6	
1014	40.4		1064	45.0		1114	53.2		1164	55.4	
1015	40.3		1065	45.0		1115	53.3		1165	55.2	
1016	40.2		1066	45.5		1116	53.4		1166	55.1	
1017	41.9		1067	46.0		1117	53.6		1167	55.2	
1018	43.7		1068	46.3		1118	53.8		1168	55.3	
1019	45.0		1069	46.6		1119	54.0		1169	55.2	
1020	45.5		1070	46.3		1120	54.2		1170	55.1	
1021	46.0		1071	46.0		1121	54.3		1171	55.1	
1022	46.4		1072	45.7		1122	54.3		1172	55.0	
1023	46.3		1073	45.4		1123	54.4		1173	55.0	
1024	46.1		1074	45.1		1124	54.6		1174	55.0	
1025	45.9		1075	44.9		1125	54.8		1175	54.9	
1026	45.7		1076	44.7		1126	54.9		1176	54.7	
1027	45.5		1077	44.5		1127	55.0		1177	54.5	
1028	45.3		1078	44.3		1128	54.8		1178	54.6	
1029	45.1		1079	44.5		1129	54.1		1179	54.6	
1030	45.0		1080	44.6		1130	52.6		1180	54.7	
1031	44.9		1081	44.8		1131	50.8		1181	54.8	
1032	44.4		1082	45.0		1132	50.2		1182	54.9	
1033	43.6		1083	45.0		1133	50.0		1183	54.8	
1034	42.4		1084	45.1		1134	50.0		1184	54.7	
1035	40.8		1085	45.8		1135	50.0		1185	54.6	
1036	38.8		1086	47.0		1136	50.0		1186	54.7	
1037	36.9		1087	48.4		1137	50.0		1187	54.7	
1038	35.5		1088	49.6		1138	50.0		1188	54.8	
1039	35.0		1089	50.9		1139	50.0		1189	54.7	
1040	35.0		1090	52.1		1140	50.0		1190	54.6	
1041	35.0		1091	53.4		1141	50.0		1191	54.7	
1042	35.0		1092	54.4		1142	50.0		1192	55.0	
1043	35.0		1093	55.0		1143	50.0		1193	55.0	
1044	35.0		1094	55.5		1144	50.0		1194	55.0	
1045	35.1		1095	56.0		1145	50.0		1195	55.0	
1046	36.3		1096	56.3		1146	50.0		1196	54.9	
1047	37.7		1097	56.5		1147	50.3		1197	54.5	
1048	39.1		1098	56.3		1148	50.9		1198	53.8	
1049	40.0		1099	56.0		1149	51.6		1199	52.7	
1050	40.5		1100	55.8		1150	52.3		1200	51.4	

APPENDIX VIII. EPA CONGESTED FREEWAY DYNAMOMETER DRIVING SCHEDULE CONTINUED

SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR	SEC	MPH	GEAR
1201	50.4		1251	55.0		1301	49.2		1351	53.[illegible]	
1202	49.8		1252	54.8		1302	49.0		1352	54.[illegible]	
1203	49.0		1253	54.5		1303	49.2		1353	54.5	
1204	48.3		1254	54.0		1304	49.1		1354	54.4	
1205	48.0		1255	53.7		1305	49.1		1355	54.4	
1206	47.9		1256	53.8		1306	49.1		1356	54.4	
1207	48.0		1257	53.7		1307	49.6		1357	54.2	
1208	48.3		1258	53.9		1308	49.9		1358	54.0	
1209	48.3		1259	54.3		1309	50.3		1359	53.6	
1210	48.3		1260	54.7		1310	51.1		1360	53.1	
1211	48.3		1261	55.0		1311	51.9		1361	53.5	
1212	48.7		1262	55.0		1312	52.7		1362	53.4	
1213	50.1		1263	54.7		1313	53.6		1363	53.4	
1214	50.3		1264	54.5		1314	54.4		1364	53.4	
1215	50.4		1265	54.8		1315	54.9		1365	53.0	
1216	50.4		1266	54.9		1316	55.1		1366	51.0	
1217	50.1		1267	55.0		1317	55.3		1367	48.0	
1218	49.9		1268	55.1		1318	55.7		1368	45.0	
1219	50.0		1269	55.1		1319	56.0		1369	42.0	
1220	50.0		1270	55.7		1320	56.2		1370	39.0	
1221	50.0		1271	56.3		1321	56.0		1371	36.0	
1222	50.2		1272	56.6		1322	55.5		1372	32.8	
1223	50.5		1273	56.8		1323	55.7		1373	29.5	
1224	50.9		1274	56.5		1324	55.7		1374	26.2	
1225	51.0		1275	56.1		1325	55.7		1375	22.9	
1226	50.7		1276	55.7		1326	55.7		1376	19.6	
1227	50.9		1277	55.6		1327	55.5		1377	16.6	
1228	50.8		1278	55.6		1328	55.7		1378	14.0	
1229	51.6		1279	55.6		1329	55.9		1379	12.0	
1230	52.3		1280	55.3		1330	56.2		1380	11.0	
1231	53.0		1281	55.0		1331	56.6		1381	10.0	(2)
1232	53.7		1282	54.9		1332	56.7		1382	10.0	
1233	54.4		1283	54.6		1333	56.3		1383	10.0	
1234	54.9		1284	54.1		1334	56.0		1384	8.8	
1235	55.1		1285	53.3		1335	56.0		1385	6.7	
1236	55.4		1286	52.3		1336	55.8		1386	4.6	
1237	56.1		1287	51.2		1337	55.7		1387	2.5	
1238	56.3		1288	50.4		1338	55.5		1388	1.5	
1239	56.3		1289	50.0		1339	55.3		1389	0.9	
1240	56.3		1290	49.7		1340	55.3		1390	0.0	
1241	56.3		1291	49.5		1341	55.3		1391	0.0	
1242	56.3		1292	49.0		1342	55.3		1392	0.0	
1243	56.3		1293	48.3		1343	55.2		1393	0.0	
1244	56.0		1294	47.8		1344	55.2		1394	0.0	
1245	55.7		1295	48.0		1345	55.0		1395	0.0	
1246	55.2		1296	48.2		1346	54.8		1396	0.0	
1247	55.0		1297	48.2		1347	54.7		1397	0.0	
1248	55.0		1298	48.3		1348	54.5		1398	0.0	
1249	55.1		1299	48.7		1349	54.0				
1250	55.2		1300	49.4		1350	53.6				

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